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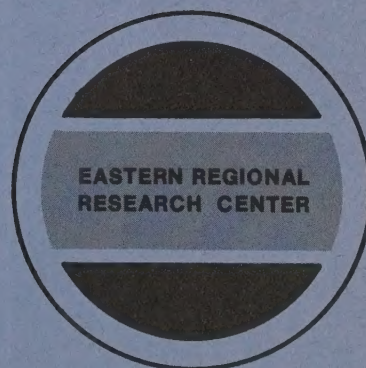
WHEY PRODUCTS CONFERENCE

held at Minneapolis, Minnesota
October 9-10, 1978

and sponsored jointly by
The Whey Products Institute
and

The U.S. Department of Agriculture

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WHEY PRODUCTS INSTITUTE
Chicago, IL 60606

and

U.S. DEPARTMENT OF AGRICULTURE
Agricultural Research
Eastern Regional Research Center
Philadelphia, PA 19118

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WELCOMING REMARKS

Pete Frigo
President, Whey Products Institute
Frigo Cheese Corporation

J. W. Harlan
Asst. Director, Eastern Regional Research Center
Science and Education Administration, USDA

Mr. Frigo

It is indeed a pleasure for me as President of the Whey Products Institute to join with Dr. Jerry Harlan, USDA Eastern Regional Research Center in welcoming you to the 1978 Whey Products Conference. As you know, this is the fifth in a series of whey conferences held every two years since 1970. The whey processing industry through the Whey Products Institute is again pleased to join with the USDA in joint sponsorship of this event.

I believe the program planning committee coordinated by Dr. Warren Clark, Executive Director of the Whey Products Institute and Dr. John Woychik of the USDA/ERRC have assembled another excellent program that will maintain your interest throughout the Conference. While it may never be possible to allot ample time for unlimited discussion, I trust you will find that sufficient time has been reserved for discussion, and you are invited to participate in the Conference by sharing your thoughts and ideas from which we all may benefit.

One of the means for keeping succeeding conferences viable is to effect variations in program format. At our last Conference, held in Atlantic City during the 1976 Dairy Show, we emphasized an International aspect and had program participants from several countries. Major Conference changes this year are the banquet and keynote address given last evening and the tour scheduled for tomorrow where you will have an opportunity to observe the detail and precision that is involved in equipment design and fabrication.

Today's program is divided primarily into two broad areas -- this morning subjects pertaining to whey processing will be discussed, whereas this afternoon the emphasis will be on whey marketing.

We have a full program planned and I am as anxious as you to get into it. So, let me conclude my remarks by again saying "Welcome." I look forward to the opportunity of visiting with you personally during the Conference.

J. W. Harlan

On behalf of the USDA, it is my pleasure to join Pete Frigo in welcoming each of you to this 1978 Whey Products Conference.

In his opening remarks at the last Whey Products Conference in 1976, our Center Director, Dr. Wolff, traced the progress and growing confidence in whey utilization by quoting Conference speakers from 1970 when the topic was "Pollution or Utilization" through 1976 when it was observed, "Wheys have taken their place as mature members among the food formulator's ingredients of choice."

While progress has been made in the past--in 1978 we still see incentives for new advances. We realize that it may be many years before our ultimate goal of full utilization of whey at a fair market price is realized, but we think this goal can be achieved by Government and industry continuing to work together as we have in the past to share in the solution of problems and identification of new opportunities.

We think that the four Conferences on Whey Products we have cosponsored since 1970 have made important contributions to progress in whey utilization by providing a forum for discussion of scientific and technological advances and new marketing opportunities. We think the fact that over 150 representatives of over 85 firms preregistered for this 5th Conference indicates that you agree that these meetings are of value.

Warren Clark of the Whey Products Institute and John Woychik of our Center have organized a program for today's Conference keyed to today's problems--with an eye to the future.

I am confident that the two technical sessions will bring out new concepts and open new doors which will make this 5th Whey Products Conference every bit as stimulating and productive as were the first four and that as you meet and talk over coffee and later return home from the conference you will be filled with the enthusiasm that comes from exposure to new ideas and with renewed confidence in the future of whey products.

KEYNOTE ADDRESS

ECUMENICISM AND EFFICIENCY--

FUTURE ISSUES IN THE AREA OF FOOD REGULATION

Edward John Allera
Food and Drug Administration

I. INTRODUCTION

In preparing this speech, I reviewed the case law, the numerous Federal Register notices that the various regulatory agencies have issued, and, God forbid, I sat down and thought. As I tried to analyze the area of food regulation and to determine what prominent issues will arise most frequently or will be the most important in the next few years, I was struck by the crucial point in time at which we stand.

After the White House Conference on Food, Nutrition, and Health in 1969, which provided an enormous informational base, the Food and Drug Administration embarked on an ambitious series of programs to improve the regulation of foods: the GRAS review,¹ the information panel,² nutrition labeling,³ nutritional equivalency for imitation foods,⁴ collective names,⁵ flavor labeling,⁶ safe and suitable policy,⁷ common or usual name policy,⁸ nutritional profiles,⁹ and vitamins and minerals,¹⁰ among others. During those halcyon days, the agency was the knight in shining armor carving innovative, refined, and efficient policies out of the labyrinthian world of food regulation.

¹ 21 CFR Part 170; 38 FR 20051; 37 FR 16407.

² 21 CFR § 101.2; 38 FR 2124, 6950; 37 FR 6993.

³ 21 CFR § 101.9; 38 FR 2125, 6951; 37 FR 6493.

⁴ 21 CFR § 101.3 (e); 38 FR 2138, 20702.

⁵ 21 CFR § 101.4.

⁶ 21 CFR § 101.22; 38 FR 2139, 20718.

⁷ 21 CFR § 130.3(d); 39 FR 17704; 38 FR 10272.

⁸ 21 CFR § 102.5; 38 FR 6964; 37 FR 12327.

⁹ 21 CFR § 104.5; 37 FR 6969; 36 FR 24822.

¹⁰ 38 FR 2143; 38 FR 20708, 20731.

Judicial review was favorable, leading one commentator to call it a phantom.¹¹

Since those high-riding days, the courts, Congress, and the public have begun seriously to reexamine and criticize FDA's regulatory actions in all areas, including food. The Vitamin and Mineral Amendments of 1976 and related case law, the Saccharin Study and Labeling Act of 1977, the laetrile controversy, and the Appropriations Committee's attempts to impede FDA action on the use of antibiotics in animal feeds exemplify the crucial framework within which future food regulation must proceed. Moreover, Proposition 13 casts a giant shadow even in this area and cries for less regulation.

FDA, which has been described as a large, slow-moving target that bleeds easily and profusely, took one lumbering giant step forward in regulating foods in the early 70's. The behemoth is now gathering information for the next step through a series of legislative-style hearings around the country.¹² From the information gathered at these hearings, the next steps forward will be perhaps the most important that the agency has taken in the last half century. More than at any time since enactment of the Federal Food, Drug, and Cosmetic Act in 1938, perhaps even since enactment of the Pure Food and Drug Act of 1906, the agency and the government face demands from all sectors for more efficient regulation and in some ways less restrictive regulation. The agency must step forward cautiously between what a philosopher has termed the negative concepts of liberty, where people are given as much freedom to choose their vices and as little regulation as possible, and the positive concepts which require an active and expanding role of the government.¹³ With this framework in mind, let us look at what I believe are two of the major issues in the future of food regulation--ecumenicism and efficiency--remembering that brevity is the soul of wit.

II. ECUMENICISM

In addition to FDA, USDA and the Federal Trade Commission are participating in the food labeling hearings. FDA is charged with regulating most aspects of the food supply, USDA regulates most aspects of meat and poultry products, and the Federal Trade Commission regulates advertising of these products.

Another area of joint agency action is the Interagency Regulatory Liaison Group (IRLG). This group consists of representatives of FDA, the Environmental Protection Agency, the Consumer Product Safety Commission, and the Occupational Safety and Health Administration, i.e., the four principal federal agencies that regulate toxic chemicals in the environment.¹⁴ The IRLG

¹¹ Austern, Food Standards: The Balance Between Certainty and Innovation, 27 Food Drug Cosm. L. J. 440, 451 (1969), hereinafter cited as Austern, Certainty and Innovation.

¹² 43 FR 1112.

¹³ I. Berlin, Two Concepts of Liberty (1958).

¹⁴ 42 FR 54856.

has formed numerous working groups, manned by additional personnel from the agencies, to facilitate regulatory action against toxic chemicals.¹⁵

Previously, the regulatory agencies have operated on separate, and ostensibly equal, footing in their respective jurisdictional areas. But the specific areas of authority are amorphous and often overlapping. Neither the broad categories of regulatory authority (e.g., food additives, meat on the hoof, meat products, GRAS substances, food advertising, or drug advertising) nor products within these categories (e.g., chlorofluorocarbons, nitrites, fertilizer, sludge, recycled animal waste, PCB's, acrylonitrile, nutrition labeling) fit neatly within the bailiwick of any one agency. Furthermore, in the past the agencies have developed separate approaches to regulating specific categories or products. Although the approaches are similar in most areas, they are not congruent, and the minor differences often cause problems for the agencies and the regulated industry.

Some people within the agencies consider their approach to dealing with a specific problem as the one true "religion" for resolving issues involved. This theocratic approach to regulation must be eliminated, and it is being eroded in part, I believe, because the agencies recognize that, at a time of increasing responsibility, increasing public skepticism, increasing costs, and decreasing appropriations, more efficient regulation is necessary to protect their individual turfs. For this reason, the call for ecumenicism and less bureaucracy is falling on receptive ears.

When a specific regulatory question arises, it is in everyone's interest, the public to be protected, the taxpayer, and the regulated industry, that the most efficient regulatory scheme be taken to facilitate debate and ultimate resolution of the issues. Only the private bar suffers under this efficient approach, and many would say justifiably so.

The best example so far of extensive ecumenical activity producing a tangible result is the joint FDA/EPA/CPSC regulation prescribing a warning statement on chlorofluorocarbon aerosols and the ultimate phase-out of non-essential uses of these products. FDA used its authority to require label declaration of all material facts and to ban products under the general safety provisions of the Federal Food, Drug, and Cosmetic Act.¹⁶ Concurrently, EPA used the recently enacted Toxic Substances Control Act (TOSCA) to prohibit the use of nonessential chlorofluorocarbon propellants, which minimized the need for separate CPSC action.¹⁷

When a problem arises involving a chemical that appears in the work place, the environment, consumer goods, and a food or a drug, several alternatives are available for selecting the type of ecumenical activity to deal with the problem. Of course, each regulatory agency can initiate regulatory action

¹⁵ 43 FR 7174.

¹⁶ See 21 CFR §§ 2.125, 173.345, 7.23, 740.11 (42 FR 22017, 43 FR 11306).

¹⁷ 15 CFR Part 712, 762, 42 FR 2452, 43 FR 1138, 11326.

against the specific chemical's use under its jurisdiction. However, the regulatory agency with the most experience in dealing with the specific chemical or the problem associated with the chemical can take the principal regulatory action (e.g., EPA has taken the lead in regulating sludge and fertilizer); the agency with the most efficient statutory scheme for regulating the product can take regulatory action (evidentiary hearings with their inherent delays should be avoided); or the agency whose authority permits choking off the principal (and profitable) uses of the chemical can take the regulatory action, thus alleviating the need for action by the other agencies.

Currently, the process for selecting a course of action is informally handled, and several legal factors are involved in selecting the proper approach. All are geared to the statutory structure of the agencies and their authority. Clearly, agencies that have a single administrator have the advantage of efficiency and economy of scale. Other factors include the statutory findings or evidentiary bases that are necessary before regulatory action can be undertaken. These vary. Also, different statutory procedures are prescribed, and they may be implemented in different ways. Moreover, the burden of proof and statutory standards of review for the actions differ.¹⁸

As the costs of regulation and the time and manpower necessary to regulate increase, I believe more ecumenical regulatory action must and will take place, if for no other reason than to prevent a legislative reorganization that will eliminate the possibility for theocratic hang ups by eliminating major segments of statutory authority and manpower.

In addition to the informal solutions described above, one intermediate solution is a statutory amendment to the Administrative Procedure Act that would override all specific regulatory statutes. The amendment would permit joint agency action under a procedure prescribed by the APA. Now, joint action is governed by the most onerous procedure imposed by the separate statutes that are being used, and this is an impediment.

In my opinion, the statutory amendment should adopt a procedure similar to the rulemaking procedure prescribed in the Toxic Substances Control Act and the Magnuson-Moss FTC Improvement Act.¹⁹ As the courts have continued to

¹⁸ The agencies administer statutes that involve licensing-like provisions (or premarket review of data) for substances and standard-setting provisions for substances that are not subject to premarket approval. The licensing procedures are essentially adjudications, while the standard-setting procedures involve informal rulemaking, formal rulemaking on a record, and hybrids of the two. Compare 7 U.S.C. § 136a; 21 U.S.C. §§ 346, 348, 355, 357, 360b, 376; and 15 U.S.C. § 2605 with 15 U.S.C. §§ 1261(q), 1262; 15 U.S.C. §§ 2056-57, 2061, 21 U.S.C. § 346; 29 U.S.C. § 655, 33 U.S.C. § 1251 et seq., 42 U.S.C. § 1857 et seq. FDA's procedures emphasize written submissions while the other agencies emphasize oral presentations.

¹⁹ 15 U.S.C. § 2605; 15 U.S.C. § 2309.

graft procedures onto the informal notice and comment rulemaking procedures²⁰ and the standards of review have become merged, this hybrid rulemaking procedure, which incorporates the opportunity for an oral presentation of comments, seems most appropriate.

One caveat is necessary, however. For it to be efficient, everyone must recognize that the procedure is legislative-like and that all notions of Rules of Evidence are inapplicable.²¹ In particular, cross-examination has become a delaying tactic inconsistent with, and unnecessary for, a full hearing and reasoned decision-making based on sound science.²² The proceedings cannot be permitted to degenerate into a trial-like motions practice prolonging the activity to a point that only the lawyers benefit--gaining financial, psychological, and probably erotic pleasure in conducting these interminable proceedings. A colloquy on the issues is necessary--not a prolonged bickering match before an Administrative Law Judge.

III. FEDERAL PREEMPTION OF STATE ACTION

As the federal agencies develop an ecumenical approach to their regulatory problems, the crucial issue becomes the extent to which state action hampers the federal regulatory role. Little is gained from an effort to develop a coordinated federal policy on an issue if that policy is undermined by one or more different state policies. Some states have not adopted the innovative food labeling programs that FDA developed in the first half of this decade as part of its first giant step; thus, there is the distinct

²⁰ Until the recent Supreme Court decision in Vermont Yankee Nuclear Power v. NPDC, ___ U.S. ___, 98 S.Ct. 1197 (1978), which upheld the appropriateness of simple notice and comment rulemaking procedures, courts were mandating the addition of trial-like procedures to the informal procedure prescribed by § 4 of the Administrative Procedure Act. For a representative list, see the cases cited at NRDC v. U.S. Nuclear Regulatory Comm'n, 547 F.2d 633, n.23 643 (D.C. Cir. 1976), rev. sub nom. Vermont Yankee Nuclear Power v. NRDC, *supra*. Since Vermont Yankee, the courts have been more subtle. They now require administrative records to support the agency actions that are almost impossible to develop with garden variety single-step notice and comment rulemaking. See, e.g., Weyerhaeuser Company, et al. v. Douglas M. Costle, Nos. 76-1674 (D.C. Cir. Sept. 5, 1978); Manufacturing Chemists Ass'n v. Douglas M. Costle, No. 78-578 (W. D. La. August 4, 1978).

²¹ It is supposedly hornbook law that the rules of evidence do not govern administrative proceedings. See Schwartz, *Administrative Law Cases During 1977*, 30 Ad. L. Rev. 167, 177 (1978). Nevertheless, the rules tend to serve as the framework for conducting such proceedings.

²² Williams, "Hybrid Rulemaking" under the Administrative Procedure Act: A Legal and Empirical Analysis, 42 U. Chi. L. Rev. 401 (1975); Hamilton, Procedures for the Adoption of Rules of General Applicability: The Need for Procedural Innovation in Administrative Rulemaking, 60 Calif. L. Rev. 1276 (1972).

possibility that some will be reluctant to adopt the programs that will result from the forthcoming second step. Also, a few states apparently have developed regulatory programs at the local level that impinge upon areas that historically have been federally regulated, and the local regulation may impede attempts by a company to develop a nationwide distribution system for its products.

It is difficult for me to conceive of any area that has been regulated more pervasively by the federal government in the past decade than the food industry. Moreover, the food distribution system is becoming more integrated, and nationwide distribution of products is the rule rather than the exception.

State regulatory programs that conflict with a federal requirement are constitutionally suspect. If the state program stands as an obstacle to the accomplishment and execution of the purposes and objectives of a federal program, the state program must fall; uniformity vital to achieve national interest is one of these purposes.²¹ Violation of these rules constitutes an unreasonable burden on interstate commerce and unconstitutionally burdens the commerce Congress sought to foster with the enactment of the FFDC Act, i.e., honest and fair labeling of safe food products.²³ Nevertheless, we must not overlook the fact that the states can serve a useful function by providing a forum for experimental regulatory programs.

As the federal government imposes new food regulations pursuant to the legislative-style hearings, the extent that different state regulations are preempted will be a continually arising question.

IV. EFFICIENCY

Assuming that the federal government and the states can coordinate their regulatory programs, the agencies then must efficiently regulate food. I would like to focus first on perhaps the most frequently discussed area of alleged inefficient food regulation (i.e., the use of food standards versus the use of common or usual names), and then I will finish with some discussion of risk/benefits.

A. Improving the Food Standards Process

1. Introduction

Foods must contain safe ingredients that are suitable for their intended purposes. An ingredient can be shown to be safe through scientific procedures or prior use in food.²⁴ It may be termed a food, food additive, GRAS substance, or prior sanctioned article.

²³ Jones v. Rath Packing Co., ___ U.S. ___, 97 S.Ct. 1305, 1317 (1977).

²⁴ CTFA vs. State of Minn., 440 F. Supp. 1216, 1223 (D. Minn. 1977), affirmed No. 78-1010 (8th Cir., May 25, 1978). See also British Airways v. Port Authority, 10 E.R.C. 1216 (2d Cir. 1977).

FDA has a program that is reviewing the safety of all previously approved and currently-in-use food ingredients, and it is publishing the results of these reviews in the Federal Register so that regulatory status of all these ingredients will be publicly known.²⁵

The labeling of the finished food product must conform to the statutorily prescribed labeling requirements, which FDA has considerably amplified through regulations. Finished foods under the FFDC Act may be divided into two very broad categories, i.e., standardized food for which FDA has promulgated a standard of identity under § 401 of the Act and nonstandardized foods for which no standard of identity exists. FDA has minimized the differences in the labeling requirements for the two categories through regulations issued under the FFDC Act.²⁶ Other types of food, i.e., imitation foods, substitute foods, and special dietary foods, are essentially subcategories that traverse the two basic groups.

Separate procedures exist for regulating the two categories of food products within the framework of the safe and suitable ingredients that make up properly labeled food products.

The procedures for establishing standards of identity are set forth in §§ 401 and 701(e) of the FFDC Act. The procedures for regulating nonstandardized foods are somewhat more diffuse and are the creation of Peter Barton Hutt's fertile mind. As I describe a little later, they are much more flexible. The current debate concerns the need for standardization of new foods and the precision or degree of elaboration that the standards should contain.

2. Standards of Identity

The concept of standards of identity was developed to protect consumers from economic fraud. As one commentator (my former boss), Richard Merrill, has noted, the idea was to assure consumers that convenience foods purchased at stores were precisely like those Mother used to make;²⁷ they were intended to assure that a standardized convenience product reflected consumers' understanding of what the homemade product contained.

The first food standards were brief. The tomato juice standard of identity contained a one paragraph description of the food, and it permitted one optional ingredient.²⁸ Similarly, the infamous standard of identity for

²⁵ 21 U.S.C. 321(s).

²⁶ See note 1 supra. 21 CFR Parts 181 and 182.

²⁷ 21 CFR §§ 101.2, 101.3(e), 101.6, 101.9, 101.

²⁸ Merrill and Collier, "Like Mother Used to Make": An Analysis of FDA Food Standards of Identity, 74 Colum. L. Rev. 561, 562-577 (1974). See also, Austern, The F-O-R-M-U-L-A-T-I-O-N of Mandatory Food Standards, 2 Food Drug Cosm. L. J. 532, 536-543 (1947).

for peanut butter was approximately three paragraphs.²⁹

By the early 1950's, approximately half of the foods marketed in this country were standardized. Over the last decade, however, the figure has diminished considerably.³⁰ An analysis of some current standards of identity illustrates that they have gone beyond the original simple "recipe" concept into a more comprehensive, almost good manufacturing process, approach. The standards of identity for some canned fruits, canned vegetables, and juices are typical standards that go on for several columns in the Code of Federal Regulations, and they set forth in extraordinary detail, requirements for food styles, sources, sizes, e.g., whole, halves, sliced, diced, half rings, pieces, stalks, spears, tips, butts, cuts, short cuts, hearts.³¹

At this point it is useful to examine the statutorily required procedure for promulgating standards:

1. FDA first issues a notice of proposed rulemaking that describes the standard's principal points and summarizes the basis for adopting each point.
2. FDA receives and evaluates written public comments on the proposal.
3. The agency then publishes a final order in the Federal Register responding to the major comments.
4. Affected parties have the opportunity to file objections to the final order, and all legally sufficient objections stay the effective date of the final order. FDA must evaluate the objections and rule on them.
5. If the objections contain data that raise a substantial issue that requires a hearing for resolution, FDA publishes another notice setting forth the issues about which there will be a full-blown evidentiary hearing, i.e., an administrative trial. Because many people have been left to guess for years about whether legally adequate objections have been filed, when objections are filed, FDA now publishes a notice staying the regulations until the objections are comprehensively analyzed and ruled on.
6. FDA holds an evidentiary hearing on the issues.
7. After the hearing, briefs are filed, and an Administrative Law Judge issues an opinion, the initial decision.
8. The parties have thirty days to file objections.
9. The Commissioner of Food and Drugs then issues a final order.

²⁹ Austern, Certainty and Innovation, *supra*, note 11 at 485, citing 21 CFR § 53.1(1969).

³⁰ 24 FR 5391 (1959). See 21 CFR § 164.150.

³¹ Austern, The Current Status of the Food-Standards Program "Eppur Si Mouve," 14 Food Drug Cosm. L. J. 208, 213 (1959).

10, The affected parties may go to court and challenge the final order.³³

Although hearings are not often required (thereby circumventing steps 6, 7, and 8), the peanut butter and vitamin and mineral hearings are legendary. In sum, this is one hell of a way to run a railroad. Further, some parties now wait until the fourth or fifth step before filing their data either to delay the procedure intentionally or merely because they recognize that the cumbersome nature of the process does not place any burden on them for expeditious compliance.

The entire procedure, known officially as rulemaking on a record, has been called "legislation by litigation."³⁴ When the term was coined by the Dean of the Food and Drug Law Bar, it was a noble appellation. Today, it symbolizes the worst of two worlds that are in disrepute. Not only does the interminable procedure that I outlined apply to establishing a food standard, it applies to every amendment that is suggested for an existing food standard.

Those that favor lengthy and detailed food standards ignore the fact that attempts to add or change even a minor point in a standard can initiate a five-year effort, and the number of amendments that will be proposed is directly proportional to the detail of the standard. Moreover, the Codex Alimentarius Commission is in the process of revising all the food standards, and, as a member of the FAO/WHO, the United States has an obligation to consider all these new food standards and determine whether the agency should adopt them, establish a targeted date of adoption, or essentially continue to regulate the article as a nonstandardized food.³⁵

3. Common or Usual Names

FDA formalized by rulemaking an approach for establishing common or usual names for nonstandardized foods. Under the rules, a nonstandardized food can be given a coined name that describes in simple, direct terms the basic nature of the food with characterizing ingredients. When the proportion of that ingredient has a material bearing on the price or consumer acceptance of the product or when the labeling or appearance create an erroneous impression, the name of the food must include the percentage of any characterizing ingredient or component.³⁶

³² 21 CFR Parts 145, 155, 156.

³³ 21 U.S.C. §§ 341 and 701; 21 CFR Part 12.

³⁴ Austern, Certainty and Innovation, *supra*, note 11, at 451.

³⁵ 21 CFR § 130.6; 38 FR 12396; 37 FR 21102. Codex Alimentarius Commission Procedural Manual (1975).

³⁶ 21 CFR § 102.5; 38 FR 6964; 37 FR 12327.

When the agency concludes that a common or usual name for a food should be formally established, it issues a Federal Register notice describing the basis for the proposal and receives written public comments. FDA then need only evaluate the comments and publish a final order dealing with them. The basic approach is quite simple, although some of the most recent common or usual name proposals are more complex.

The proposal for vegetable plant protein products contains nutritional profiles of the various products,³⁷ and they are more complex scientifically than the first regulations. Due to changes necessitated by the public comments and the technology, FDA issued a tentative final order which is analogous to a reproposal. Therefore, the agency must now review and respond to a new round of comments and then issue a final order.

As you can see, even with the tentative final order, the legal procedures for establishing a common or usual name regulation are much simpler than those for establishing or amending food standards. In the absence of a statutory revision, FDA nevertheless is taking strides to make the food standards process more efficient and competitive with the regulations for nonstandardized foods. A comparison of the proposed food standards for substitute cheeses,³⁸ including the pasteurized process cheese products,³⁹ and the proposal on the vegetable plant protein products shows "converging parallel" schemes of regulation that will be the key to future regulation of foods. The proponents of food standards suffer from an inherent handicap due to the complex procedures required by statute. Only a statutory revision that streamlines the procedures and makes the process of establishing and amending food standards simpler is compatible with economic and efficient government regulation. Acceptable alternatives to rulemaking on a record are notice and comment rulemaking or hybrid rulemaking, described above.

4. Food Formulary

For those who believe food standards should be complex and identify in excruciating detail every bit of information about a food, an alternative is available to establishing such a food standard by regulation. The alternative is, in my opinion, far more in keeping with the original Congressional intent for food standards. The original function of publishing standards in the Code of Federal Regulations was to provide consumers with a reference to review the simple recipe of a food to check the quality of the standard with their perception of the food. We have gone far beyond that. Additionally, suggestions for extensive ingredient labeling in food, while commendable, will raise more problems. Total labeling will be difficult for the industry to satisfy from a practical standpoint. Culling the suggestions for information to be put on labels will be difficult for the agencies and involve many difficult judgments. All will be costly, and the costs ultimately will be passed on to the consumer.

³⁷ 43 FR 30472.

³⁸ 43 FR 42118.

³⁹ 42 FR 53970.

As an alternative, I propose a federal food formulary to supplement a statutorily streamlined procedure for promulgating food standards and administratively streamlined standards. An examination of most food packages shows that product information that will satisfy almost every consumer in the world, including precise formulation information, is available simply by writing to the manufacturer. Since this material is publicly available, an alternative to complex government regulatory programs is to collect the information and publish it in a formulary. The formulary could be managed by the federal government, a private educational institution, e.g., the Food and Drug Law Institute, a trade association, or a consumer group. The possibilities are endless. Nevertheless, it would satisfy the concerns of those people who believe that all food should be covered by precise standards so that the public can determine everything they wanted to know about a food but never asked. Because the formulary would permit general food standards, those who believe flexibility is necessary in the manufacturing process also will be satisfied.

B. Risk/Benefit Calculations

At the risk of being too lengthy, I would like to turn now to a subject that will be the topic of much discussion this winter--risk/benefit calculations in the food supply. This topic will reach new prominence when the National Academy of Sciences releases its reports on saccharin and general food safety. Although the results are unknown now, an historical perspective may be useful. Twenty years ago the argument ran that no one could calculate the risks associated with additives, but one could easily quantitate the benefits of additives in our food supply. Today the argument is the converse. We have much confidence in statistical procedures for assessing at least risks of cancer and mutagenicity of additives, but our ability to calculate quantitatively the benefits of these articles is fuzzy.

Some use of quantitative risk assessment in regulating the food supply should, and probably will, be adopted. The agencies will do this either administratively where permitted or Congress will amend the statutes to mandate risk assessments in all food safety areas. Risk assessment hopefully will place the debate about how "safe" is "safe" in perspective and improve the government's ability to regulate toxic chemicals, especially carcinogens and mutagens.

V. CONCLUSION

The next few years will be critical for the federal regulatory agencies in general and the food regulatory agencies in particular. Ecumenicism and efficiency will be crucial to improving the regulatory system, and the movement toward these has begun. Like all burgeoning movements, the early years are the most difficult, and the fervor of its disciples must be strong enough to move the mountains of tradition that stand in its path. In my opinion, the fervor is there.

LOW ENERGY WATER REMOVAL FROM HEAT SENSITIVE

LIQUID FOODS

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We have recently started work on a project jointly funded by the U.S. Department of Energy and the U.S. Department of Agriculture to study water removal from heat sensitive liquid foods by various combinations of reverse osmosis, freeze-concentration and evaporation to determine which combination will use minimum energy without sacrifice of product quality. Hopefully, this combination will also represent the minimum cost.

Though our current research is concerned with skim milk, our project should be of interest to those concerned with whey, since the colligative properties upon which these three methods are based depend primarily on the lactose and mineral content; this is the same for both fluids. Though inherently less energy intensive, reverse osmosis and freeze concentration, because of high capital cost, high operating cost, product loss, and flavor loss, have not been able to compete with evaporation as a method for concentrating liquid foods. In addition, and probably of greatest importance, these two methods have been considered solely on an either/or basis. The fact that either of these processes can be used in conjunction with thermal evaporation has been ignored. They are ideally suited energywise in the initial stage of concentration where most of the water is removed. Also both are most efficient below 30-40% solids.

Currently, evaporation is carried out as the first step in drying (40-50% solids), to produce frozen concentrates, e.g., orange juice (ca 45% solids), or concentrated fruit juices of 65% used in jelly and candy making. These highly concentrated fruit juices are self-preserving and do not require refrigeration. Though drying may be a second step, evaporation is the major step in water removal. For example, if we concentrate skim milk to 40% solids before drying, we have to remove 85% of the water originally present. In fact, to go from an initial solids content of 9.1% to 16.7% entails a removal of 50% of the water.

Since 1973 the cost of steam has risen from \$.50/1000 lb to around \$4.00/1000 lb; hence, the Department of Energy has made evaporation a prime target for industrial energy conservation and has recently issued two publications (1,2) describing how to upgrade the energy efficiency of current evaporation systems requiring low, moderate, or large capital investments. Low investment improvements are nothing but good engineering practice, such as proper venting and prevention of leakage and fouling by operating at pressure for which the system was designed. Moderate investment improvements consist of adding heat recovery equipment and instrumentation. Large capital investment modifications involve installing additional effects and use of mechanical vapor recompression. The latter can also be used in tandem with existing evaporation systems.

There is no doubt that adding effects, if done properly, will improve energy efficiency. However, adding effects is not suitable for heat sensitive liquids (such as skim milk and fruit juices) for two reasons. First, to maintain capacity the temperature must be raised in the first effect (1,2). Second, the residence time in the evaporator will be increased (1,2).

Mechanical vapor recompression is also disadvantageous with heat sensitive liquids, not only because of the high capital investment required but also freeze concentration and reverse osmosis use less energy.

The spiraling energy costs and the inadequacy of the foregoing approach when applied to heat sensitive liquids have forced a reappraisal of reverse osmosis and freeze concentration. Because of recent technological advances, they are certainly back in the picture, especially when considered as part of the overall water removal scheme and not solely on an either/or basis. Let us review some of the more important developments. First, the developments in membrane technology leading to an ever increasing use of this technology on an industrial scale; this can only act as a catalyst for the further development of improved systems. Second, loss of flavor components; this was a serious defect of reverse osmosis. Recent theoretical developments have shown that separation of various substances can be predicted; the theory has been applied to the recovery of apple flavor components by reverse osmosis (3). The next three developments pertain to freeze concentration. For effectively preventing loss of solids in the washing step (a previous defect) large crystals are necessary. Research has demonstrated that this can be effected by separating the heat transfer step from the crystallizing step and allowing the crystals to grow in a tank (4). Another major development is the gravity wash column (5); this has eliminated the need for centrifuges, presses, and piston operated columns, reducing energy requirements as well as product loss caused by entrainment in the ice.

Finally, there have been other significant developments resulting from the desalination program which I describe in greater detail when I discuss our research plans.

Some idea of the incentives for studying these two processes can be seen in the energy consumption for various processes shown in Table I. To have a common basis of comparison the third column gives the energy consumption on the basis of oil burned; for electricity the efficiency used was 35%, while for the thermal evaporators an 80% efficiency at the boilerhouse was used.

There are two types of freeze concentration processes listed. The direct freezing process or vacuum flash freezing is so termed because the refrigerant—in this case, water—directly contacts the liquid being concentrated. In the indirect method there is no contact and a heat exchanger is required.

The direct freezing process uses the least energy, almost $\frac{1}{2}$ the amount used in the first indirect process listed and which was also developed in the desalination program (6). The figures for the indirect process are

TABLE I.--Energy requirements for various concentration processes

Process	KW hr/1000 gal	BTU/lb	BTU/lb (as oil burned)
<u>Freeze conc.</u>			
Direct	40	16.3	46.7
Indirect ¹	75	30.7	87.7
Indirect ²	370	151.3	432
<u>Evaporation³</u>			
Single effect	-	1250	1562.5
Triple effect	-	417	520.8
MVR ⁴	145	59.3	169.4
<u>Membrane</u>			
Reverse osmosis ⁵	85.6	35.0	100

¹Based on 25,000 GPD desalination plant.

²Does not include steam for melting ice.

³Does not include electricity for pumps, etc.

⁴Evaporating whey @ 120°F.

⁵Report 1977 DOE workshop on food processing RO = 10 effects.

based on data taken from a 25,000 GPD desalination plant (7). While not as good as the direct process, this indirect process is better energywise than any other concentration method including reverse osmosis. The other indirect process listed is a Dutch process currently used (8), with scraped heat exchangers and piston operated wash columns; ice is melted by external steam. The figures given here do not include this steam which would make its energy consumption pretty much the same as, if not worse than, the triple effect evaporators.

Consumption figures for the single and triple effect evaporators were based on the assumption that one pound of steam evaporates 0.8 lb of water per effect. The mechanical vapor recompression system in Table I was reported for a whey concentrating system (9). While more efficient than thermal evaporation, it uses significantly more energy than reverse osmosis or freeze concentration.

The figure for reverse osmosis was taken from a 1977 Department of Energy Workshop (10). In this report, reverse osmosis was stated to be equivalent to 10 effects. No other information was given, so I used a figure of 100 in the third column and worked back to the other numbers.

However, these figures should be used with caution. When first compared, freeze concentration wins going away. But let us remember these data are from different sources. Different starting materials were used. What works for sea water may not work for skim milk. This is particularly true for the gravity wash column. Cost factors must be considered. Finally, let us not lose sight of our research objective: What combination of methods is the optimum, costwise and energywise? Perhaps one method will prove to be the optimum. We really do not know. Hopefully, the research plan sketched here can give us the answer.

1. Reverse Osmosis

Table II shows our overall research plans. We have just purchased a reverse osmosis laboratory-size plate and frame unit which will be used to test membranes and to develop an appropriate cleaning regime for each liquid food we study. Our choice of the plate and frame type does not mean that we have ruled out the other configurations. However, one aspect of our research is concerned with membrane testing. Currently, a lot of work is going on in developing new membranes. The plate and frame configuration would simplify the problem of testing these membranes; all we will need is a sheet of the material. The other configurations would require the fabrication of the special modules that each configuration and make requires.

TABLE II.--Research plan

Reverse osmosis	Freeze concentration	Evaporation
1. <u>Lab studies</u>	1. <u>Lab studies</u>	
A. Membrane testing	A. Physico-chemical studies	A. Assemble data for optimization
B. Cleaning regime	B. Develop process control methods	B. Obtain some data in ED pilot plant
2. <u>Pilot plant</u>	2. <u>Pilot plant</u>	
Obtain data for cost optimization	and energy optimization	

Our objective in pilot plant studies is to obtain data so that a mathematical model relating concentration and quality to energy consumption and cost can be developed. An extended test under actual plant conditions will have to be made. As yet we have not developed a final plan for this phase and probably will not until we complete the laboratory studies.

2. Freeze Concentration

The laboratory studies have as their objective the determination of physicochemical data, such as the freezing point and phase studies, which will be used in the pilot plant study. For example, does lactose precipitate out? If so, in what range? Will the protein cause any difficulties? These are some of the problems we are now studying or thinking about.

The other phase of the laboratory work is to develop appropriate process control methods. For example, we are considering the use of the refractive index in determining solids concentration. Crystal size is a critical factor in the washing step. For successful washing the size should be at least 200 microns in diameter. We are currently designing a monitoring system which will enable us to visually monitor the crystal growth development and also detect the precipitation of other compounds such as lactose.

The equipment we will use in our proposed pilot plant studies is shown in Figure 1. This is a schematic diagram of a 250 gallon per day pilot plant unit being built for us which embodies the latest developments of the desalination program. In effect, we are asking the question: Can we successfully transfer the desalination technology to the food concentration industry? This is an indirect cooling system in which the refrigerant does not come in contact with the liquid being concentrated. First of all, the conventional scraped wall heat exchanger is replaced by a shell and tube evaporator. The tube bundle is compartmentalized and operates cyclically, one compartment being on a thaw cycle to melt the ice which has built up on the inside of the tubes. Second, the refrigerant, before it goes to the condenser, is used to melt the ice which is then used for washing the slurry and precooling the feed. The net result is a significantly lower energy consumption than that of the Dutch process currently used in the food industry (8). The unit will also have provisions for bringing in fresh water for washing. Washing will be carried out in the gravity column.

Before I discuss the direct cooling unit in which the refrigerant water actually contacts the liquid which is being concentrated, I would like to discuss the physicochemical principles upon which the direct cooling system is based. Figure 2 shows the phase diagram for pure water and sea water (11). For pure water the three equilibrium lines intersect in (what is called) the triple point. Here, three phases, solid (ice), liquid, and vapor coexist at a temperature of 0.0100°C and a vapor pressure of 4.580 mm.

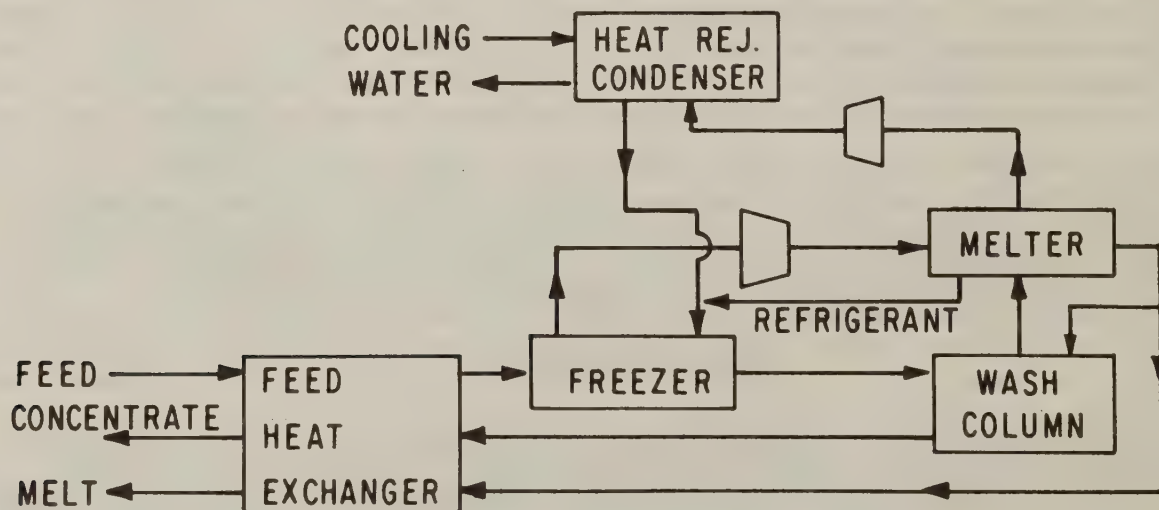


Figure 1.--Indirect freezing.

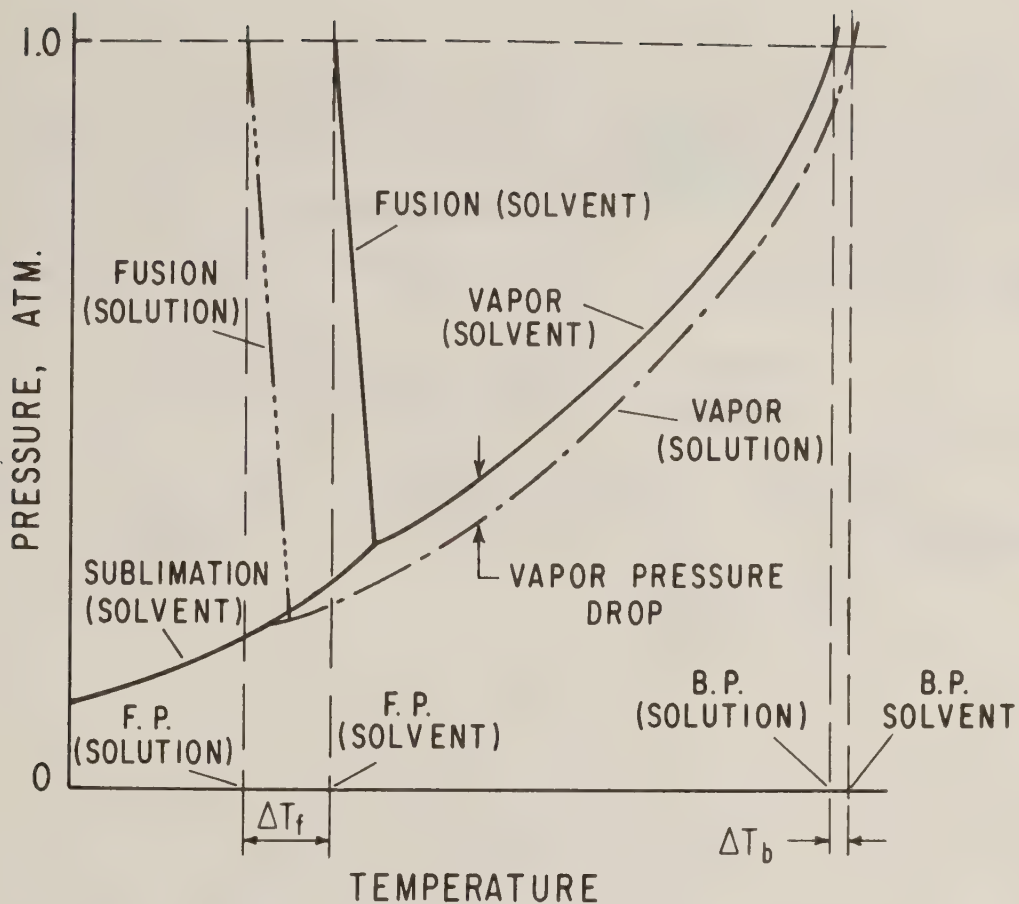


Figure 2.--Phase diagram for sea water and pure water

These conditions are invariant; in fact, units termed triple point cells are used to calibrate thermometers. The line below the pure water vapor equilibrium line represents the boiling point rise for a solution such as sea water for a range of pressures from atmospheric to below that corresponding to the triple-point pressure. The line to the left of the pure water freezing point line represents the freezing point line of the solution for the same range. It intersects the solution boiling point line at a unique point different from that of pure water. Obviously for a range of concentrations we will have a point for each concentration. The points, then, lie on a line which is the locus of all triple points for the given range of concentration. This means that if we bring feed in at a low concentration we can concentrate it to a solids content corresponding to the temperature and pressure of the triple point line if the equipment is being operated at these conditions. Furthermore, each pound of water evaporated removes 1000 BTU's from the solution; this freezes 7 pounds of water, since the latent heat of fusion is about 1/7 the heat of vaporization. In the direct vacuum freezing systems the vaporized water is considered the refrigerant and hence, instead of being removed by a vacuum pump, it is compressed (as any other refrigerant) and used to melt the ice from the wash column as in the indirect system. Since we are operating roughly between the freezing point of the solution and the freezing point of water, we approach the ideal refrigerating system for water, one that will require the minimum energy.

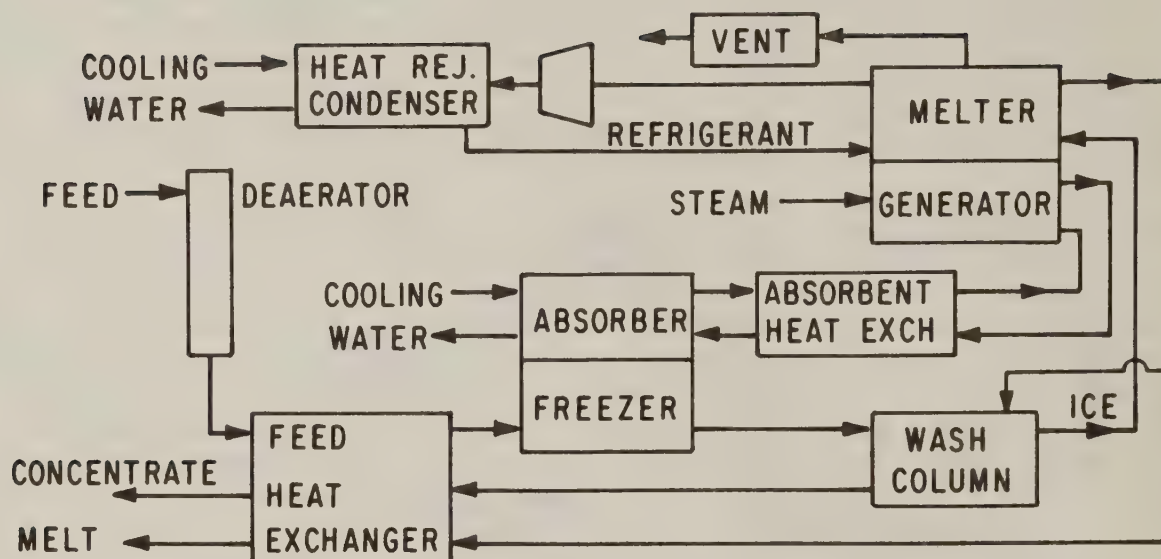


Figure 3.--Absorption freezing.

Figure 3 shows a schematic diagram of the direct freezing system being built for us but which will not be ready for at least another year. Conceptually it is similar to the system just described, with one major difference. Instead of a compressor to compress the water vapor, an absorption system is substituted. Hence, this system bears the same relationship to the vacuum freezing vapor compression system that ammonia absorption refrigeration bears to the vapor compression refrigeration system which is used in conventional refrigeration. It operates as follows. The entire system is under vacuum. Deaerated feed passes through a heat exchanger into the freezer. Water vapor from the freezer is absorbed by an absorbent which is a saturated solution of a salt such as LiBr or NaOH. This solution has a vapor pressure lower than that of the water at the prevailing pressure and temperature. Provisions exist for keeping it cool as it absorbs water vapor. The dilute solution passes through a heat exchanger countercurrent to the concentrated solution from the generator. It enters the generator, where it is then concentrated. The generator has an external source of heat such as waste steam, hot water, or even a heat pump. Part of the vapor evaporated in the generator melts the ice and is condensed. The excess water vapor is condensed by a refrigerating cycle. The condensed water vapor and melted ice are then used for washing the slurry. The refrigeration cycle can also be run as follows. The refrigerant passes through the absorber, cools it, and rejects its heat to the generator. The ice is melted by vapor from the generator. The refrigerating cycle can also be used to melt the ice. I have only briefly sketched out how the system works. Obviously, there are any number of heat transfer networks possible, either considering the system individually or as part of an overall water removal scheme involving other unit operations.

We decided to study both types of systems because each has its merits and demerits. The direct systems use less energy but are more complex. Additionally, if fruit juices are to be concentrated by the direct method, an efficient aroma recovery process has to be developed. Based on the opinion of experts in freeze concentration processes, the direct freeze concentration is more economical at rates greater than 200,000 gallons per day (GPD), while indirect freeze concentration is more economical at rates below 50,000 GPD. Since food processing plants handle between 50,000 and 200,000 GPD this is another question to which we need the answer in the freeze concentration studies.

As in the reverse osmosis studies, our objective is to develop a mathematical model relating product concentration and quality to energy consumption and cost for both freeze concentration systems. Most of the data in optimizing the evaporation phase will be drawn from the literature and industrial sources. Some of the data on heat transfer coefficients can also be obtained in our pilot plant.

How are we going to handle these functions once we have developed them? At this point our mathematician and computer experts enter the picture. Accurate optimizing requires the proper mathematical model and computer program. One approach that we will try is the use of a new optimizing technique called geometric programming (GP) (12). This involves setting up a function, called the objective function which represents either total cost or total energy, i.e., the sum of the cost or energy function for each concentration method. Derivatives are taken and costs or energy are then distributed over the different concentration methods. The total cost or energy is then found. A policy is then developed to attain this total cost and total energy, i.e., a plant is designed for this cost or energy consumption.

Mathematics in many of its aspects is an experimental science. Hence, before we can start feeding pilot plant data into the computer, we have to test the proposed approach using data from the literature and any other available source to see if we can develop the appropriate model. If the GP technique fails, then we will go to the other more complicated models which we will be able to use, since we are currently expanding our computer capacity by tying into the large Washington, D.C., 370 computer.

If the rationale described is correct, and if our research plans succeed, just what can we hope to accomplish in conserving energy used in food processing? Right now, concentration of liquid foods uses 10 million barrels of oil annually. The new technologies proposed apparently are capable of reducing this. Today, everyone is keenly interested in preserving nutritional and organoleptic quality. These low temperature processes can certainly do this. How about cost? This is a gray area, though the engineers who are designing our equipment have presented a cost analysis showing that the indirect method is cheaper than triple effect evaporation (7). Since this was based on data extrapolated from a 25,000 GPD desalination plant, the cost still must be considered only an educated guess. Finally, if we can achieve the energy requirements realized in desalination we can save about 7.5 million barrels annually, a goal certainly justifying our efforts.

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INITIAL EXPERIENCE WITH MECHANICAL

VAPOR RECOMPRESSION EVAPORATOR

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Northland Foods Cooperative

INTRODUCTION

Was it really that long ago that we figured steam to cost 50¢-75¢ per 1,000 pounds? When we needed an evaporator, we could use a triple or double effect system and make a profit on the product. As we became more conscious of fuel costs, we were able to go to thermo compressors and boost efficiencies and steam economy.

We are all aware that the days of cheap steam are over. Northland's fuel costs have gone from \$18,000 to \$45,000 per month over the last four years. We had all of the evaporator capacity that we required, but our fuel costs began sapping our profits.

We felt that there had to be a more economical way to operate. In this age of increased energy consciousness, someone should have developed a technique to evaporate water from whey at a lower cost. In checking with people in the industry, we found that the most cost-efficient system available today is the mechanical vapor recompression evaporator.

HISTORY

Mechanical compression is not something new. The Swiss developed the concept back in the 1930's. The process concept did not gain wide acceptance here because steam was cheap. For the Swiss, even then, the costs of fuels were high. With hydroelectric power available, electricity was relatively inexpensive. The substitution of electrical power for steam was economically feasible.

In the United States, with abundant low-cost natural gas and oil, this was not the case. Here, only where hydroelectric power made electricity less expensive than gas or oil were the first mechanical compression systems installed. Now we are all faced with not only more and more expensive fuels but growing concern for their continuous availability. The last two winters have shown how the dairy industry fares in fuel allotments. We can have and have had our natural gas supply cut off.

BASIC OPERATION

The basic operating concept of mechanical vapor recompression is shown in Figure 1. All of the vapors generated during evaporation are sent to a single-stage centrifugal compressor. The compressor increases their pressure. The discharged vapors, now at a higher temperature, are used as the steam source for evaporation. The only source of power required is the electricity to run the motor on the compressor.

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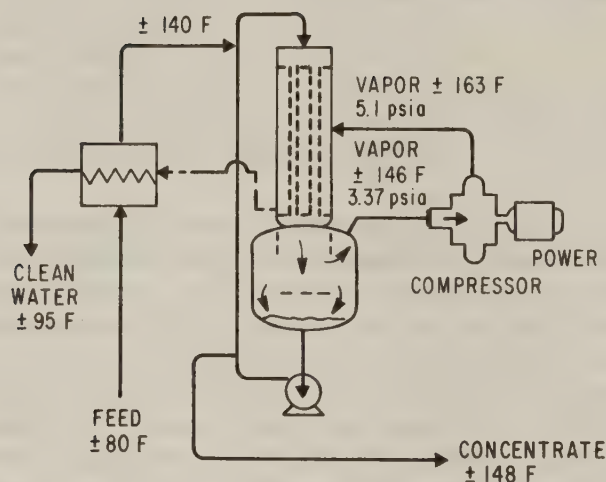


Figure 1

Since we are only increasing the pressure of the vapors rather than going through a phase change, the energy efficiency of this technique is very high. Table I compares the amount of energy required to evaporate 1,000 pounds/hour of water for multiple-effect evaporators and mechanical compression. Even with a high-efficiency steam evaporator operating at a steam economy of six pounds of evaporation per pound of motive steam, the energy required to evaporate 1,000 pounds/hour of water is four times that required for a mechanical compression system.

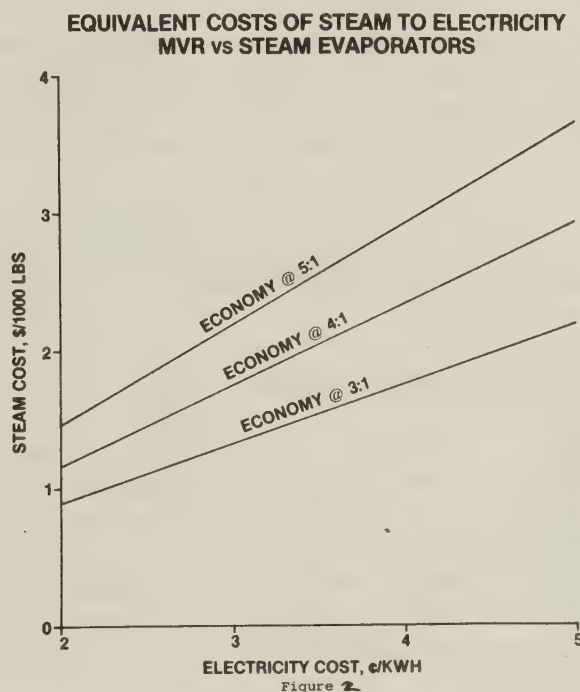
TABLE I.--Comparison of energy required to evaporate 1000 #/HR

Multiple effect steam system @ 3:1 economy - 400,000 BTU/hr
@ 4:1 economy - 300,000 BTU/hr
@ 5:1 economy - 240,000 BTU/hr
@ 6:1 economy - 200,000 BTU/hr

Mechanical vapor recompression - 50,000 BTU/hr

ECONOMICS

A BTU of electricity, however, does not cost the same as a BTU of steam. Figure 2 relates the steam costs necessary for steam systems at varying economics to equal the operating cost of a mechanical compression system operating at different electrical costs. For example, if you have a multiple-effect system operating at a steam economy of 4:1 and your plant has an electrical cost of 3¢/KWH, your plant would have to have steam costs of \$1.75/1,000 pounds to equal the operating costs of the mechanical compression system. Conversely, with the same multiple-effect system, if your steam costs were \$3.50/1,000 pounds, your electrical costs would have to be as high as 6¢/KWH before they equalled your steam costs.



In considering operating costs, it is important to figure your true cost of steam, not just the cost of fuel oil or natural gas.

No one can predict how fast the prices of fuels will increase. Since the utilities can use coal, water power, and atomic energy as well as gas and oil, it seems logical that electrical rates should rise at the same or slower rate than boiler fuels.

We think that the savings we can achieve today are significant. We anticipate an annual savings of a quarter-million dollars.

NORTHLAND'S REQUIREMENTS

Being convinced of the economic advantages of mechanical compression, we began talking with suppliers of evaporation systems about our needs, high solids concentration. We found some interesting things. Nobody has ever supplied a mechanical vapor recompression system for high solids concentration. No one was willing to guarantee that his proposed system would work. Some companies would not even touch it. We finally found one company that not only felt that they could make a system work but would guarantee it.

The Unitech Division of Ecodyne Corporation had extensive experience in mechanical vapor recompression. They had systems operating as long as six years on a wide variety of streams: distillery solubles, pulp and paper liquors, and even salt crystallizers. Their systems had evaporation rates of 30,000 to 450,000 pounds per hour. They also had developed some unique evaporator designs to enable them to handle high solids without product burn-on. Their unique PRF © (Preheat Rising/Falling Film) design had already shown it could reach 65% solids on other organic liquors of high viscosity, which tend to burn on heating surfaces, with chemical cleaning required only on a weekly or even monthly basis.

After convincing ourselves that their experience, all "non-dairy," could lead to a successful system, we purchased one of their units to be utilized as a whey hi-concentrator.

NORTHLAND'S SYSTEM OPERATION

Our system is shown in Figure 3. Its start-up vacuum is established by use of a liquid ring vacuum pump. Start-up steam is added. A Dresser single-stage centrifugal compressor, Figure 4, is turned on with its inlet guide vanes closed and the vapor recycle line fully open. Whey flow is begun, and operating levels are established. As the compressor operation stabilizes, opening the guide vanes and closing down on the recycle, the start-up steam is gradually reduced and finally shut off.

Cold condensed whey, 30% to 40%, is preheated first in tubular heaters fed by the vapors from a flash cooler and then in a plate preheater fed by the vapor condensate we are making. The whey is then pasteurized before entering the first stage of the evaporator.

Here we have Unitech's unique PRF design. The whey flows through three passes: a preheat section (fully flooded), a rising film section, and finally a falling film section. The vapors generated are carried along with the whey, not released. This approach allows each turn to be made with good whey distribution without the use of any type of distribution plate. The combined whey and vapor flow reaching 100 feet/second are separated in the first vapor body. The vapors rise and go to a demister chamber where they pass through two types of entrainment separation, vane type and mesh type. The whey goes down and is pumped to the second stage where the same PRF design is used. Again vapors are separated from the whey in the vapor body, from which they pass to the demister chamber for separation of droplets from the vapors.

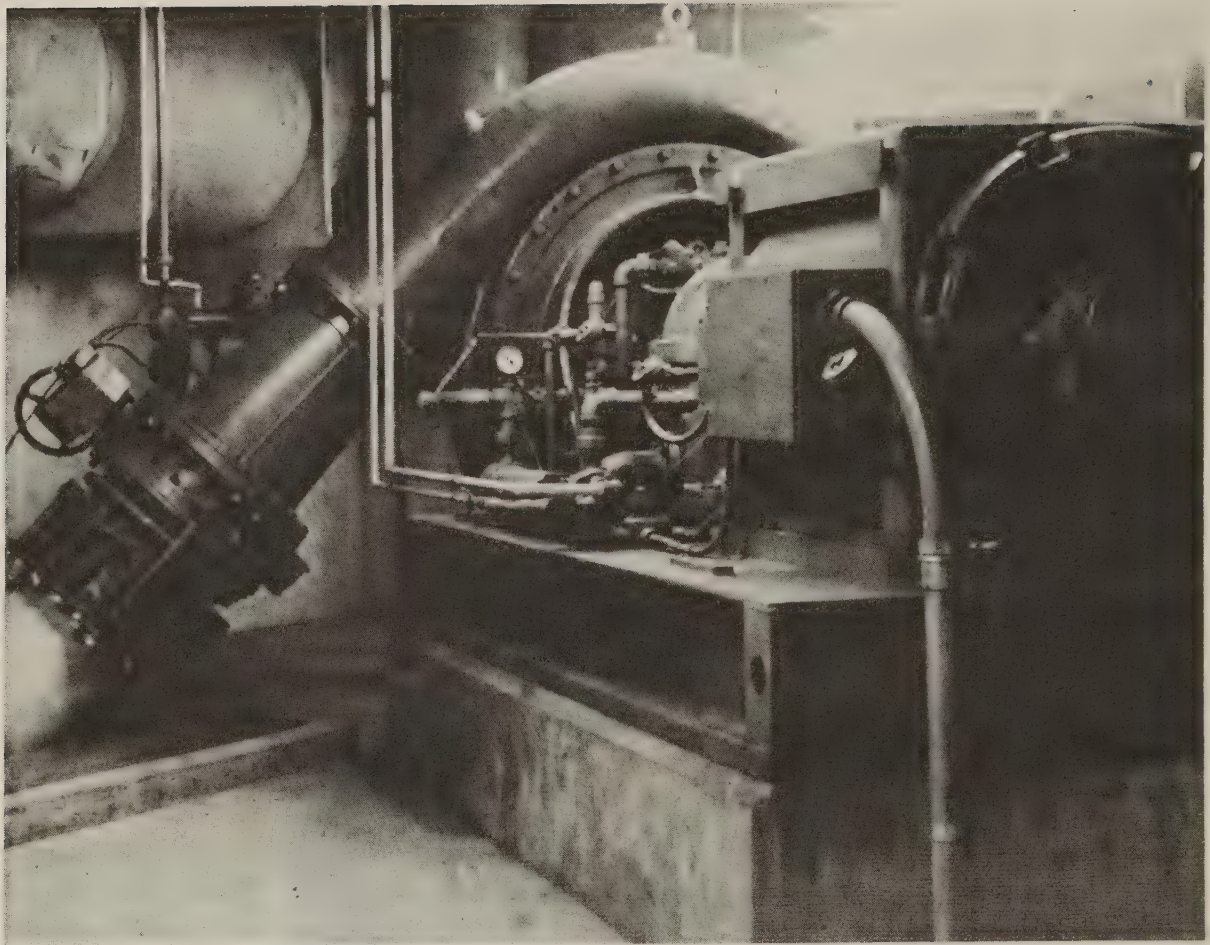


Figure 4

The whey concentrate is finally pumped to a flash cooler where the solids are brought to 52% to 56% and the temperature is dropped to 85° to 90°F.

The vapors from the demister chamber are sent to a Dresser single-stage centrifugal compressor, Figure 4, where they are mixed with the same amount of recycled vapors. This recycle insures that the vapors entering the compressor are super-heated enough to be "dry." The compressor increases the vapor pressure about 1.7 psi and raises the temperature from about 150°F to 240°F.

The discharge vapors are super-heated to about 76°F because of the inefficiency of the compressor. A flow of condensate desuper-heats the vapor to produce a larger quantity of saturated vapors at about 166°F. These saturated vapors flow to both heating elements as the source of steam for evaporation.

As the vapors condense, they are withdrawn to a condensate receiver. They are then pumped to the plate heater to preheat the inlet whey.

The Unitech system uses more sophisticated methods of entrainment separation than we have normally encountered in the dairy industry. This dual separation, vane-type separator followed by a mesh-type, produces a vapor with very low solids content, which are expected to be 5 ppm or less. This level not only serves to protect the compressor but also allows the resultant condensate to have a very low B.O.D.

THE CONTINUING IMPACT OF THE ENVIRONMENTAL

ERA ON THE DAIRY INDUSTRY

Kenneth S. Watson
Harza Engineering Company

In the last few years we have witnessed a national overreaction in the environmental control field. The pendulum has now swung too far toward environmental control regardless of cost.

For many years prior to this, the laws in most states were adequate to properly regulate pollution, but the legislatures failed to appropriate adequate funds to get the job done. Further, industry and municipality did not, on their own volition, move rapidly enough on pollution control to prevent many sections of the nation from being seriously affected by various types of pollution.

In the absence of adequate local funding, more and more funds for environmental control were advanced by the Federal Government. As Federal funds for local purposes grew, this was followed by Federal laws, rules, and regulations to police the spending of the funds. This process has continued until this nation today has by far the most massive, comprehensive, and overlapping network of environmental control laws ever conceived by the mind of man.

In the process described, the states probably inadvertently surrendered their regulatory birthright over pollution control to the Federal Government. This is now being fully realized and many of the states are struggling to regain lost ground. This does not make the compliance task of industry any easier because in some areas two sets of regulations and standards must be met.

The massive nature of the Federal program, of course, makes it quite costly. In the general direction of outlining some concept of the costs, I will quote figures from the McGraw Hill Economics Department (1). This Department estimated that some \$10.92 billion will be spent in 1978 in combating air, water, and solid wastes pollution. Some \$3.94 billion or 36% of the total estimated expenditure is slated for water pollution control.

Apparently because the United States Congress felt that environmental control in the hands of the states had been poorly handled and its own early efforts had not been much better, it attempted to reach too far down into the minute details of operating the programs in developing the laws for the various efforts now underway. Because Congressmen and staff members are not expert in the pollution control field and speed is now presumed to be of the essence, large sums of money are being spent for control purposes for which the costs are not being justified by the benefits accruing.

The Congress in its 1977 session began to recognize that it had probably overreacted in the water pollution control field with the passage of PL 92-500 in 1972 and passed the 1977 Clean Waters Act to amend the original law. This amendment effort in general improved the enabling legislation under which the program is now being carried out, but it did not go far enough to correct all the important deficiencies. Therefore, in spite of some effort to bring reasonableness into the nation's programs of environmental control, industry and municipality must continue to operate in the environmental area in which corrective action must be taken because the laws and regulations require it and not necessarily because it can be justified on sound economic grounds. Hopefully, with the passage of time, the national effort can be moved toward one that can be justified on a more rational basis, but this can have little effect on the control and treatment which must be provided at present.

In this presentation today, therefore, the almost unbelievable magnitude of environmental laws and regulations with which industry and municipality must comply will be examined. In this coverage particular attention will be given to the dairy industry.

Next, the type program which an industrial plant should have underway to keep pace with the evolving and tightening regulations of the environmental era will be briefly considered.

Finally, a short discussion of what appears to be the optimum approach to coping with the whey situation, which represents the dairy industry's most significant problem, will conclude the paper.

The Federal Regulatory Program

EPA administers six major environmental control acts which are having and will continue to have major impacts on dairy industry plants as well as other industrial plants. These acts are summarized in Table I (2) and for the most part each is complex enough that this total paper could be devoted to it. These regulatory acts cover subject matter extending from clean air, through water pollution control, resources conservation and recovery, and toxic substances. Although this appears to be somewhat inconsistent, in May of 1978 the EPA announced that over 130 new regulations were being considered for adoption under these six acts, apparently to simplify and make the programs more workable. Table I also summarizes the number of new regulations under consideration under each act.

It is apparent that programs under all the acts are evolving. Therefore, to keep this paper to reasonable length, brief consideration will be given only to matters of consequence currently under consideration by EPA in the water pollution control field, of interest to the dairy industry. These items should be somewhat representative of the myriads of developments taking place in all the environmental control areas. Major items in the water pollution control field currently receiving EPA attention are summarized in Table II. Water pollution control has been selected as the area for coverage because probably more dairy plants will find this to be their most significant area of concern.

TABLE I.--Enabling legislation now in effect and upcoming
EPA regulatory actions

Act	Number of Regulations Being Considered
The Clean Air Act (CAA)	41
The Federal Water Pollution Control Act (FWPC)	57
The Safe Drinking Water Act (SDWA)	2
The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	10
The Resources Conservation and Recovery Act (RCRA)	9
The Toxic Substances Control Act (TSCA)	14

TABLE II.--Water pollution control

Area of Interest	Action
User Charges	Industry Must Pay Proportional Part
Industrial Cost Recovery	18-Month Moratorium Industrial Payment Determine if Benefits Justify Cost
Water Quality Standards	State Standards Directed by EPA - Based on Aquatic Life
Identification of Conventional Pollutants	Important for Plants Discharging into Municipal Systems
Pretreatment Standards	Such Standards are Being Developed to be Issued Shortly

Water Pollution Control

In the user charge area, an industrial plant connected into a municipal system is required, as has been the case for some time, to pay its proportionate part of the costs of treatment provided. This is obviously a proper concept. The 1977 amendment provides for the use of ad valorem taxes to collect user charges from residential and small non-residential users. It was hoped that the same approach also would be authorized for industry to eliminate the complexity of the industrial cost recovery (ICR) approach.

It will be remembered that on the ICR provision of PL 92-500, many industries have taken the position that their costs of operation will be greater than revenues developed. For this reason, in the 1977 amendments an 18-month moratorium of payment by industry was granted for EPA to make a study of the soundness of the industrial cost recovery approach. I think that the outcome of the study will be a recommendation that ICR be continued, complex or not.

The water quality standards to be adopted by the states under EPA guidance are of significant concern as a result of the Federal fishable, swimmable mandate. This mandate will permit EPA to require all waters, in spite of enormous costs and regardless of whether their major use is industrial or public water supply, to meet the miniscule types of limits necessary to protect aquatic life. Every reasonable pressure needs to be exercised on EPA to permit the states to be able to grant a variance where the costs of treatment cannot be justified by stream benefits which will accrue. The deadline for receiving comments on this issue was September 8, 1978, so the final regulation has not yet been issued by EPA.

At present EPA is in the process of issuing a regulation which will identify conventional pollutants. In the initial listing in the July 28, 1978, issue of the Federal Register (3) four parameters, BOD, total suspended solids, fecal coliform bacteria, and pH, were designated as conventional pollutants. Three other parameters were proposed for possible addition to the list: COD, phosphorus, and oil and grease. Comments were requested as to whether the proposed items should be added to the list. It is of great significance to the dairy industry, as a result of the large number of plants connected into municipal systems, that animal and vegetable fats, oils, and greases be classified as conventional pollutants. It is hoped that they will be thus classified when the final regulation is issued, but there is no assurance this will happen. The end of the comment period was September 26, 1978, and the final outcome has not yet been announced.

Another item now under consideration by EPA is that of the setting of pretreatment standards or guidelines industry by industry. In the May issuance of regulations under consideration, the preparation of guidelines for 37 generic industries was announced. EPA is calling them guidelines, but when they reach the hands of local municipalities, they will become standards. It is encouraging to note that the dairy industry was not on the list so EPA must consider these wastes as compatible. Congratulations to the industry may be premature, however, because it can be added to the list later if animal and vegetable fats, oils, and greases are ruled incompatible.

Industry and municipality not only have to operate under the inclinations of EPA to continuously tighten requirements but the Ecology Organizations keep bringing suits against the Agency because it is not moving rapidly enough. Recently, in the August 16, 1978, issue of the Federal Register, under the Resource Conservation and Recovery Act, the EPA announced an educational conference because three environmental groups have declared their intention to commence legal action because of failure to promulgate certain regulations under the act. Such actions have been filed in the past against the Agency under most of the acts. These types of actions tend to put EPA in the middle between attempting to exercise some reason on behalf of the entities which must provide treatment and the ecologists who demand treatment regardless of costs.

In addition to dealing with environmental regulations under the jurisdiction of EPA, plants also must face up to compliance with the regulations under the Occupational Safety and Health Act (OSHA). Noise control and attenuation, falling under the jurisdiction of OSHA, perhaps are more closely related to the environmental control areas summarized in Table I, than other areas of responsibility, so they are often administered by the environmental personnel of corporations thus staffed. Further, as a result of the energy crunch, plants will have to comply with evolving regulations emanating from the Department of Energy (DOE).

Optimum Plant Program

Firms and plants today should have evaluation, control, and correction programs underway to keep upgrading their manufacturing installations environmentally to keep pace with the evolving Federal program. Volumes could be written about this approach, but efforts will be made in this section of the paper, consistent with preserving reasonable length, to put together just a skeleton outline of the type program a plant should have underway to minimize problems with the regulatory agencies. The details of this type program are being outlined more for the benefits of plants without professional environmental personnel than those thus manned.

First the plant should be surveyed to determine just what its status is, under the various acts and local ramifications of same, covered in Table I. Table III summarizes the steps a plant should take to attempt to keep pace with the ever tightening environmental climate. An audit will represent a data summary which will show in what areas plant improvements should be made and serve as a data base against which improvements can be measured. From the audit a stepwise upgrading plan should be developed and the plan recorded in a report. The report would thus become a roadmap for a program toward less probability of confrontations of having serious problems with the regulatory agencies.

Table IV summarizes the major environmental areas which should be audited. These range from water supply through wastewater control, air pollution control, solids waste handling, noise reduction, and proper energy utilization. Areas which require particular attention will vary from plant to plant, and some areas of concern can be deleted by some plants.

TABLE III.--Action to minimize a plant's regulatory problems

Make an Environmental Audit

Develop a Stepwise Upgrading Plan

Summarize the Plan in a Report

Follow the Steps of the Report Toward Improvement in Environmental Areas

TABLE IV.--The audit program necessary

The Degree and Extent of Compliance

The Water Situation

Evaluation of Wastewater Conditions

Air Pollution Control Progress

Are Solid Wastes Being Properly Handled?

What About Proper Noise Control?

Is Energy Being Properly Used?

Experience in heading the environmental control program for a major firm in the dairy and food industry indicates that plant personnel may be so involved in production operations that it is improbable that proper attention will be given to the environmental control field. This is particularly true where the plant is not large enough to justify employing a professional in the environmental field or is not part of a firm with such corporate competence. Under such circumstances, probably the best answer is for the plant to retain the services of a consulting engineering firm which is particularly competent in the generic industrial environmental control area under consideration.

Water Pollution Control

Following the concept of looking in some detail at the water pollution control area, the major items to be covered in an audit of this area are listed in Table V. It should be rather self evident why these six areas should be part of an audit of the water pollution control situation of a plant.

The form of audit tables is usually tailored to fit the needs of a particular plant. Tables VI and VII supply some concept of general information which is desirable and the type of forms used to accumulate it.

Fortunately, there are benefits other than pollution control accruing to a plant that devises a sound, on-going program to keep pace with the environmental control area. Some thought concerning the situation will confirm the fact that much of the pollution problem has its origin in loss of raw materials, intermediate products, and finished products. Thus the water, air, and solids wastes areas can be brought more completely under control by reducing such losses to the maximum extent. In the process, cost reductions of real consequence can be achieved in some plants.

Beyond the conservation of product, attention to the proper use of water will pay substantial dividends in plants that are large water users. Efforts in this area are particularly beneficial because they also will reduce the magnitude of the waste problem.

Moving toward the optimum use of energy can also represent a cost reduction of appreciable consequence in some plants in addition to coming down on the responsible corporate citizenship side of a serious national issue.

The Use and Disposal of Whey

Obviously whey contains food and feed nutrients which should be recovered for the vital purpose of contributing to feeding the world's massive population and the domestic animals upon which it depends. Therefore, those plants which generate enough whey to make it economical to use evaporation and drying for the production of whey powder for use as food and feed supplements are following the optimum approach to the solution of the whey problems. They further are making a contribution to the welfare of the people by conserving important nutrients that would otherwise be lost because profits in the production of whey powder are not always outstanding.

TABLE V.--Audit evaluation of wastewater

What Quantities and Types?

Is Appropriate In-Plant, Short-of-Treatment Action Being Taken?

If Applicable, are Services and Surcharges Equitable?

If Treatment Plant is Operated, are Costs Sound?

If Applicable, is Treatment Plant Properly Designed?

Is Proper Supervision Provided for Wastewater Area?

TABLE VI.--Wastewater cost \$ summary

(LISTING PROJECTIONS FOR CURRENT YEAR AND DATA FOR PAST TWO YEARS)			
<u>PERTINENT INFORMATION</u>	<u>COST</u>	<u>COST</u>	<u>COST</u>
TOTAL FOR YEAR			
AVERAGE PER DAY			
MAXIMUM MONTH			
MAXIMUM DAY			
<u>ADDITIONAL DETAILS</u>	<u>% OF TOTAL</u>	<u>% OF TOTAL</u>	<u>% OF TOTAL</u>
HYDRAULIC VOLUME			
BOD			
SUSPENDED SOLIDS			
FATS, OILS, & GREASES			
TOTALS			

TABLE VII.--Wastewater summary

(PROJECTED FOR CURRENT YEAR AND
LISTED FOR TWO PREVIOUS YEARS)

DISCHARGE GALLONS

ANNUALLY

MAXIMUM DAY

AVERAGE DAILY

DAILY AVERAGE, MAXIMUM MONTH

LOAD DISCHARGED LBS.

BOD

PER YEAR

AVERAGE DAILY

MAXIMUM MONTH
(DAILY AVE.)

MAXIMUM DAY

Solving the whey situation does not eliminate the pollution load of the plant, but the remainder of the load is generally handled in a city treatment plant. The only improvement to this approach which occurs to one with chemical engineering training is if the whey producers could challenge the chemical industry to take a harder look at the composition of whey perhaps the array of by-products recoverable could be extended and thus the profitability of this approach improved.

Since the solution of the problem for the sizable plants and smaller plants which are so clumped that they can build and operate joint recovery facilities has been briefly covered, attention will next be directed to the myriad of smaller plants which cannot afford to build and operate recovery facilities. This is also an important segment of the industry because the cheese it produces also makes a substantial contribution to feeding the world's masses. Most of such small plants are located adjacent to villages, but the whey cannot be discharged into these small community systems because the systems cannot satisfactorily treat the load presented.

There is an answer for such plants, however, because whey happens to contain plant nutrients reasonably representative of a balanced fertilizer. Because the regulatory agencies appeared to have some questions about the possibility of land spreading of whey without creating pollution problems, Kraft, Inc., funded a project in the hands of the Department of Soil Science at the University of Wisconsin, Madison, to evaluate the benefits of spreading whey on agricultural land, and the development of guidelines for such spreading without creating pollution problems.

In the remainder of this paper the techniques used in carrying out this project and the results obtained will be briefly covered for primarily the representatives of the smaller plants.

The University of Wisconsin Project

This evaluation project was carried out at the University of Wisconsin, Arlington Experimental Farm (4). Whey was land-spread, by pump and spray, on a series of 15 square foot plots of fallow soil to be planted in corn and at about the same time to similarly sized plots of meadow land. The purpose of this work was to evaluate the phosphorus, potassium, and nitrate nitrogen impact on the soil underlying the plots and increases in crop yield of the plots as a result of using the whey. Application of 2, 4, 8, and 16 inches of whey was made to a series of the two types of plots mentioned. Two control plots of each type were surveyed in parallel to the dosed plots. One of these received nothing and the other 8 inches of water.

The quantities of whey specified were applied in the fall of 1972 and the spring of 1973. In addition, on one series of plots double dosing in the fall and spring in the amount specified was practiced. Dosing well above what was anticipated would ever be used was carried out to determine any ill effects which might result. No more dosing of whey was practiced, but the plots were monitored for a number of years after dosing to establish the long range effects.

Figures 1, 2, and 3 show, respectively, the concentrations of nitrate nitrogen, phosphorus, and potassium in the fallow soil underlaying these plots. Figures 4, 5, and 6 show, respectively, the concentrations of nitrate nitrogen, phosphorus, and potassium underlaying the sod plots dosed.

The first foot of the profile shows the greatest impact from the dosing of all three elements for both the fallow soil and the sod. There is no tendency of consequence for the elements to carry through the profiles being monitored into the ground water table. Obviously, higher concentrations in the upper portion of the profile are desirable because the plant root zone will draw more of its nutrients from this area.

Table VIII shows the yield of corn in 1973 and 1974. The 1973 yield shown is from plots dosed only in the fall of 1972. The three yields shown in 1974 are from a series of plots dosed: in 1972 only, in 1973 only, and then double dosed during both years. 1973 was a particularly good growing year and 1974 a poor growing year. Particularly the 16 and 32 inch dosing levels represented far more whey than optimum for growing corn.

Table IX shows the hay yield for 1973 and 1974. The hay yield figures for 1974 were somewhat better than those for 1973, indicating that lack of moisture in this year did not cut back on hay products to the extent that was true of corn production. However, hay production also dropped where the excessive amounts of 16 and 32 inches of whey were applied.

In a later paper (5), profile conditions for the fallow soil plots in 1974 were compared with those prevailing in 1977. Figure 7 and 8 show this comparison for phosphorus and potassium, respectively, for the two years in question. Since corn had been grown annually on the plots, the 1977 curves clearly show to what degree these nutrients have been removed by the growing crop.

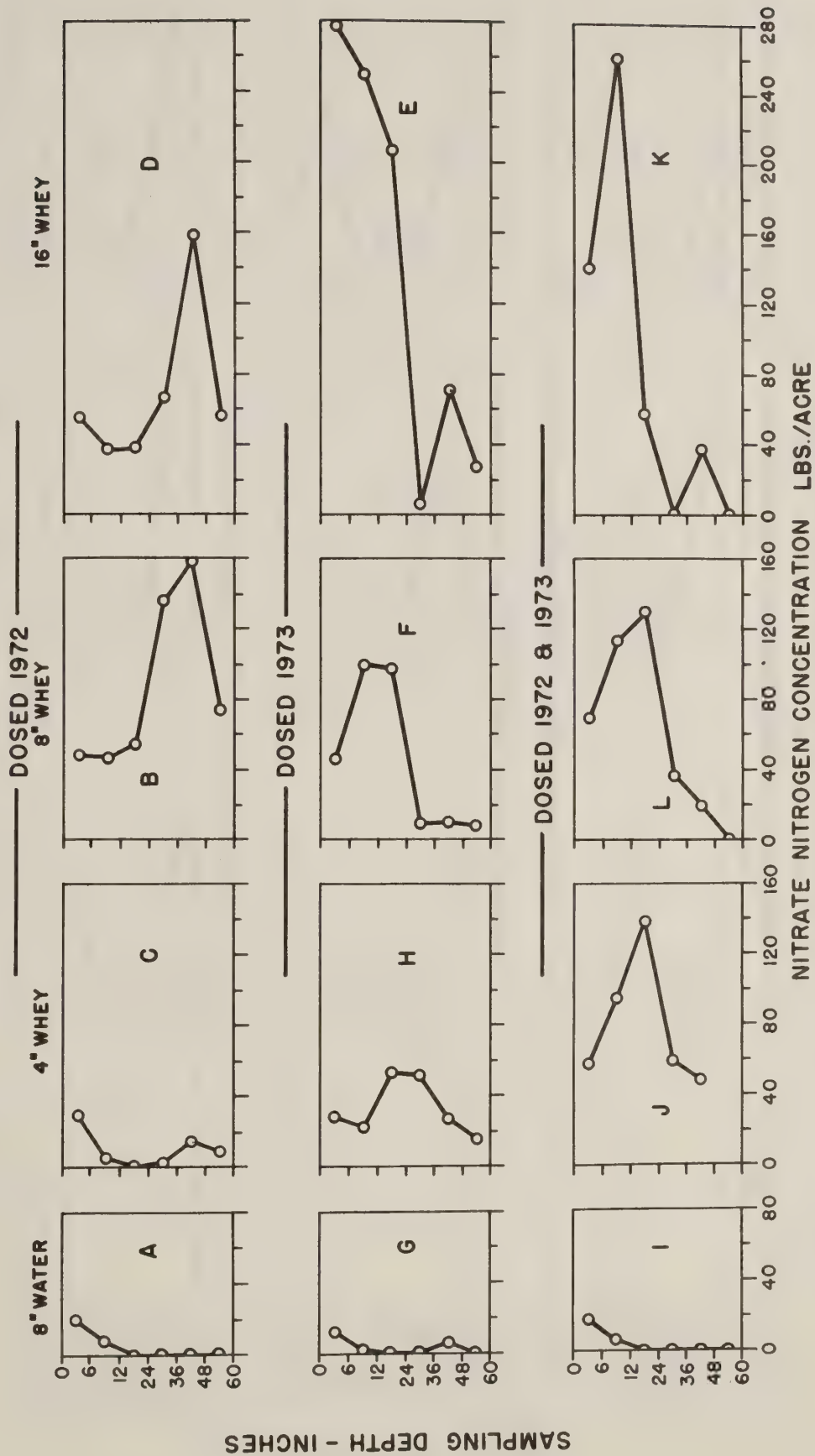
Another advantage of spreading whey is that it improves the porosity of the soil, thus retaining much more of the rainfall in the soil. This obviously has a tendency to improve the productivity of the soil. Figure 9 shows that the use of 8 inches of whey provides maximum porosity, with 4 inches of whey being almost as effective. The use of 16 inches of whey is less beneficial toward improving porosity than either 4 or 8 inches of whey.

In the later paper corn yields from the plots through 1977 were also reported. Table X summarizes such yields. In 1975, some 3 years after the spreading, the corn production was 135.6 bushels, or an excellent yield, for the 16-inch dosed plot, indicating that the nutrients are still present and contributing to the yield. The year 1976 was not very productive, but in 1977 the yield from this plot was again good. In the 32-inch dosed plot, as a result of excess dosage, the yield was poor in 1975, improved in 1976, and came into its own in 1977.

Conclusions

As a result of carrying out this project, conclusions as follows can be drawn:

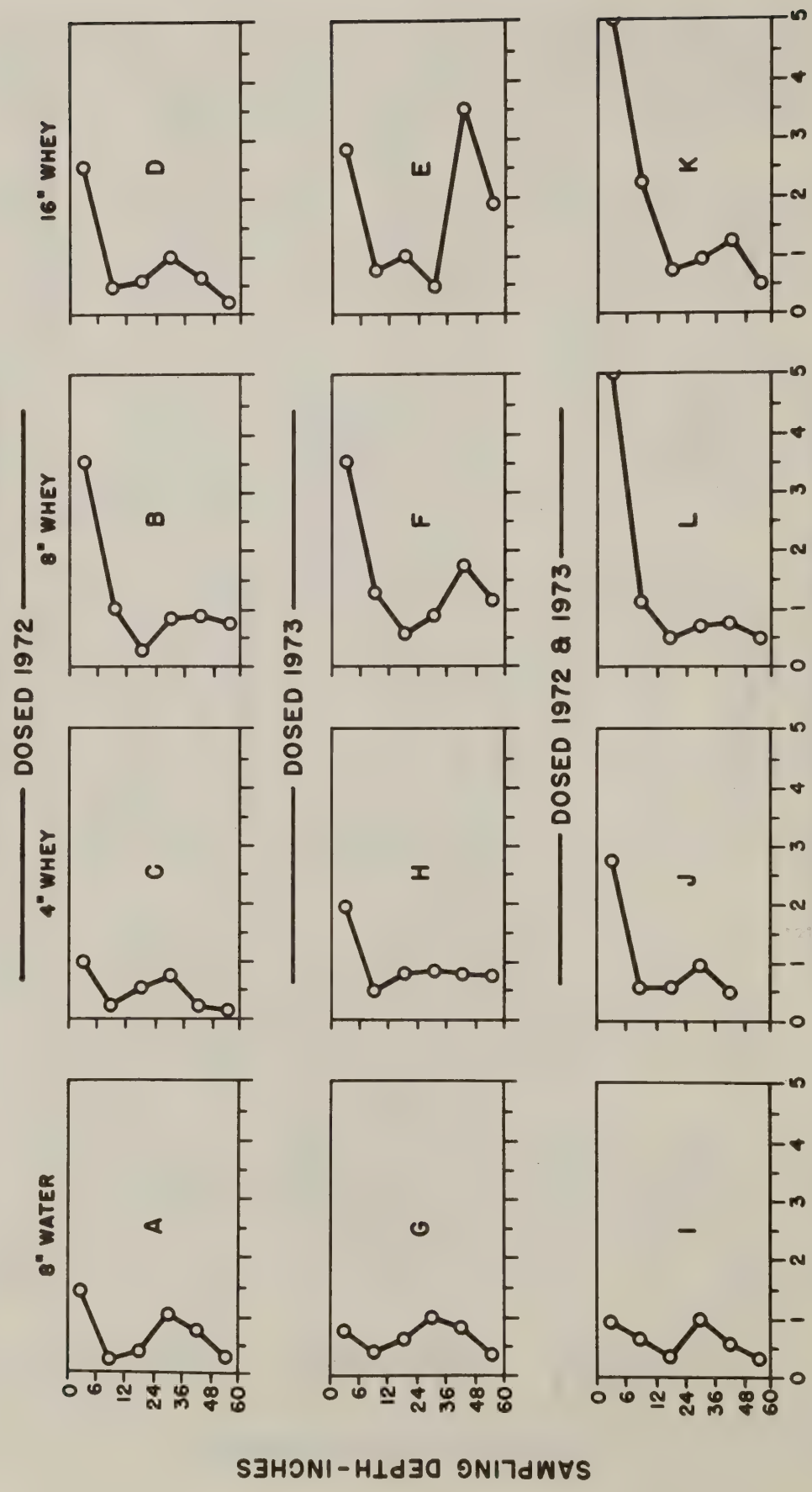
WHEY SPREADING AND NITRATE NITROGEN IN FALLOW SOIL



LETTERS A THROUGH L REPRESENT TEST PLOTS FROM FIGURE 4. PLOTS SAMPLED OCT. 1974
ARLINGTON EXPERIMENTAL FARM, UNIVERSITY OF WISCONSIN

Figure 1

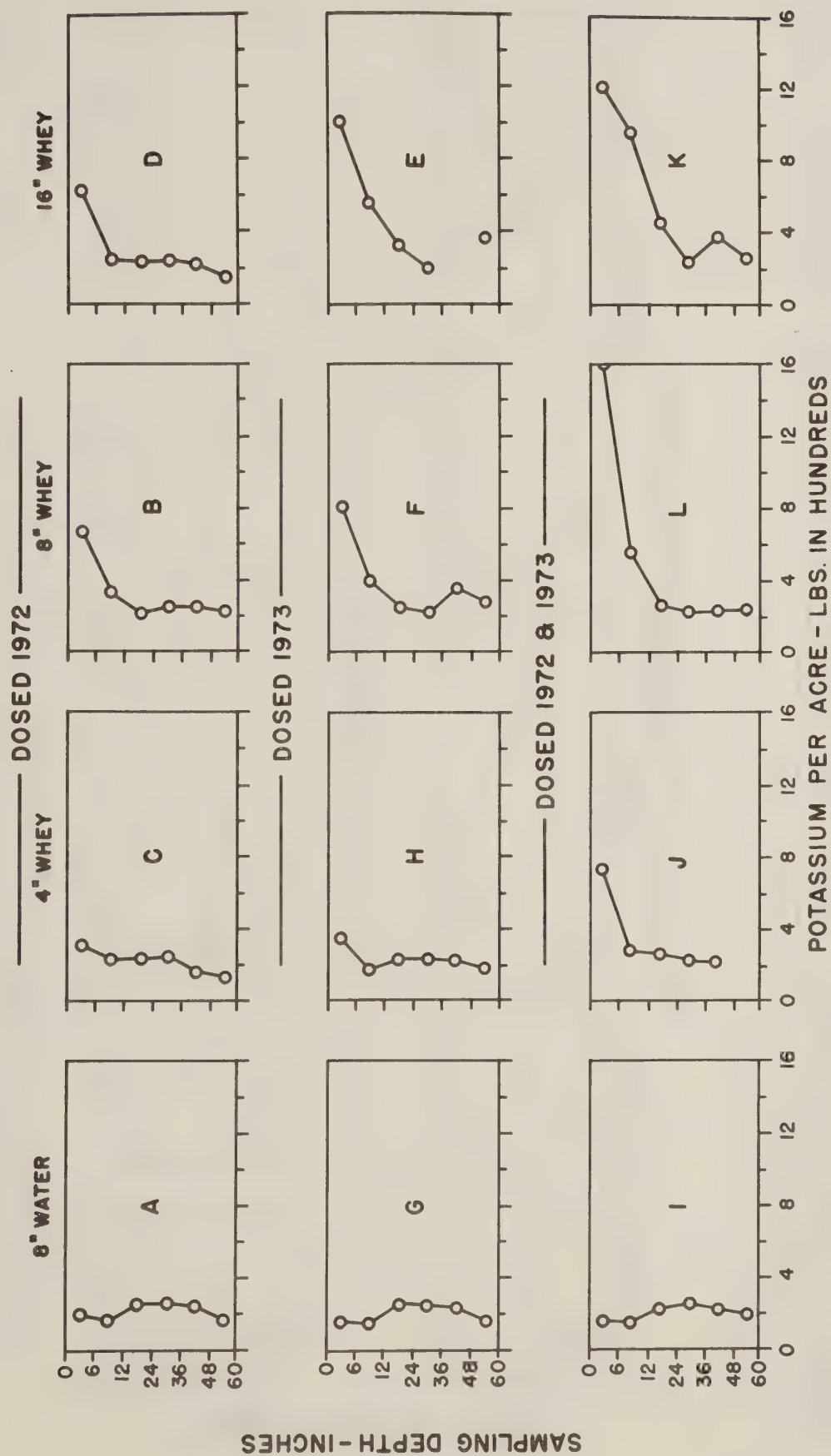
WHEY SPREADING AND PHOSPHORUS IN FALLOW SOIL



LETTERS A THROUGH L REPRESENT TEST PLOTS FROM FIGURE 4. PLOTS SAMPLED OCT. 1974
ARLINGTON EXPERIMENTAL FARM, UNIVERSITY OF WISCONSIN

Figure 2

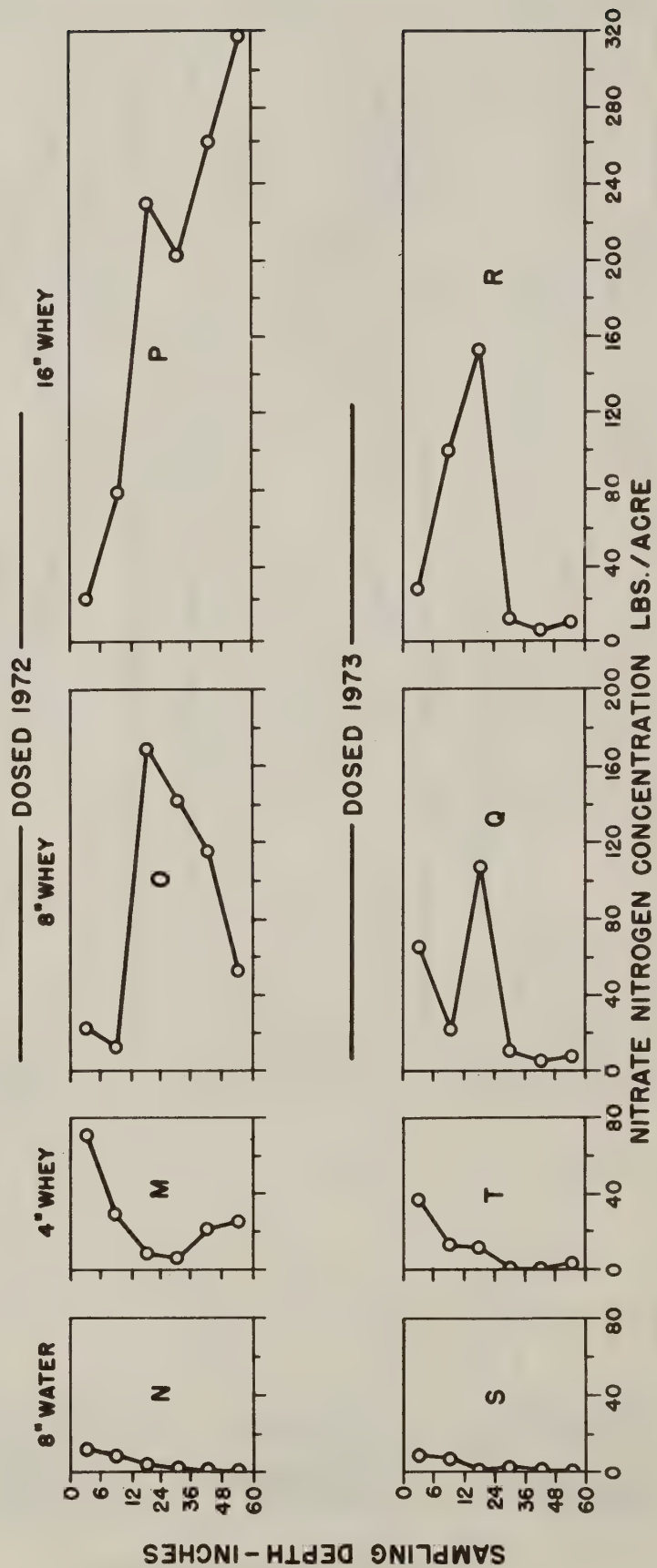
WHEY SPREADING AND POTASSIUM IN FALLOW SOIL



LETTERS A THROUGH L REPRESENT TEST PLOTS FROM FIGURE 4. PLOTS SAMPLED OCT. 1974
ARLINGTON EXPERIMENTAL FARM, UNIVERSITY OF WISCONSIN

Figure 3

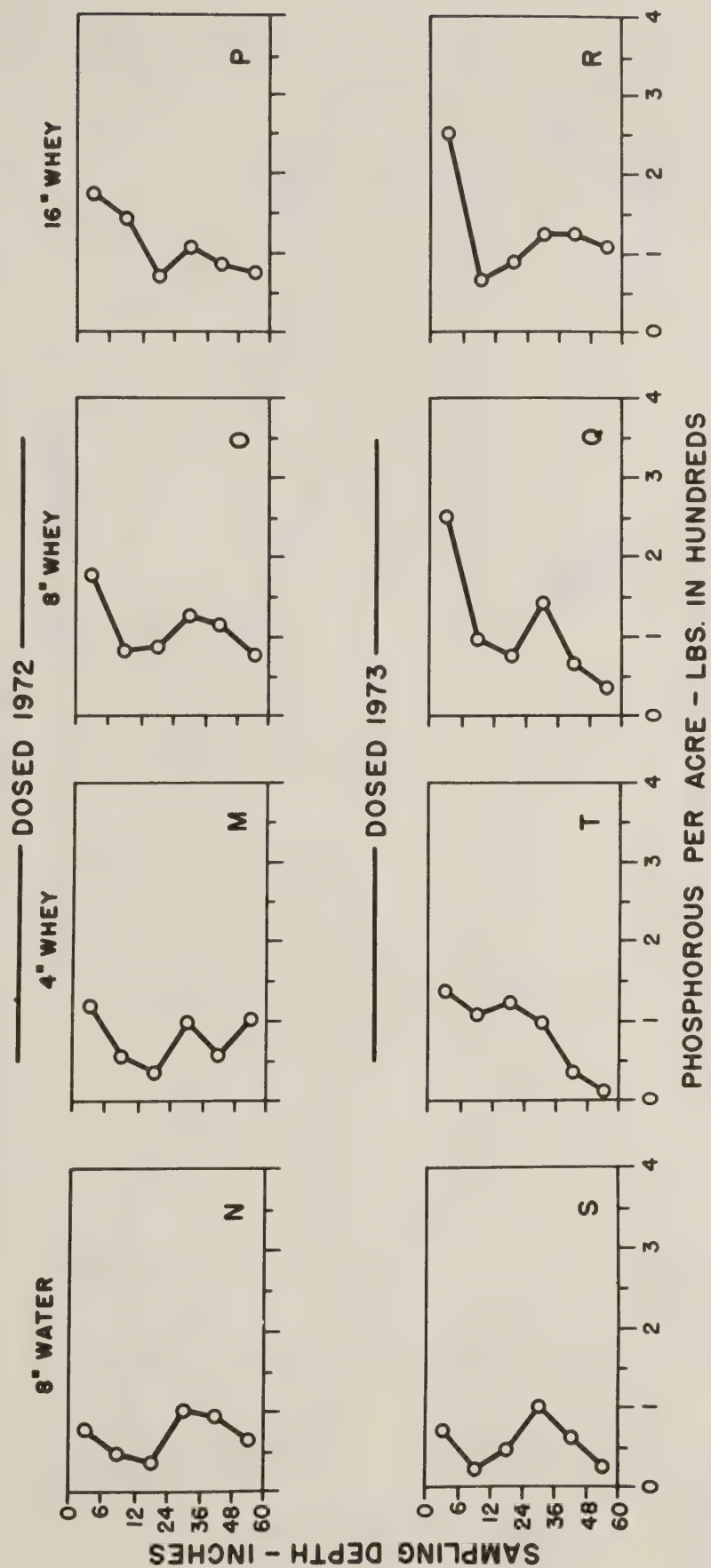
WHEY SPREADING AND NITRATE NITROGEN UNDER SOD



LETTERS M THROUGH T REPRESENT PLOTS FROM FIGURE 5. PLOTS SAMPLED OCT. 1974
ARLINGTON EXPERIMENTAL FARM, UNIVERSITY OF WISCONSIN

Figure 4

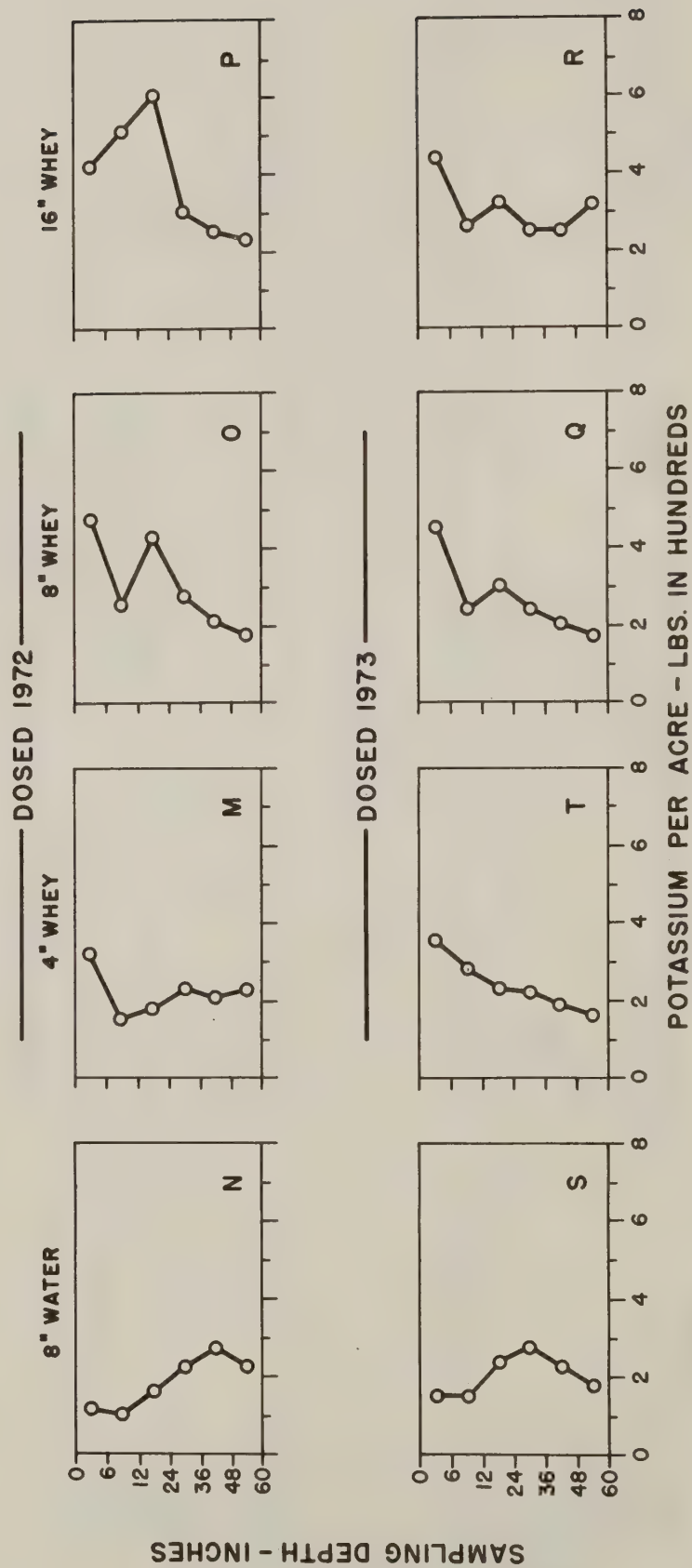
WHEY SPREADING AND PHOSPHORUS UNDER SOD



NOTE: Letters M through T represent plots from FIGURE 5 Plots sampled Oct. 1974
Arlington Experimental Farm, University of Wisconsin

Figure 5

WHEY SPREADING AND POTASSIUM UNDER SOD



LETTERS M THROUGH T REPRESENT TEST PLOTS FROM FIGURE 5. PLOTS SAMPLED OCT. 1974
ARLINGTON EXPERIMENTAL FARM, UNIVERSITY OF WISCONSIN

Figure 6

TABLE VIII.--Corn yield from whey-treated plots

TREATMENT	YIELD BUSHEL/ACRE AT 15.5% MOISTURE			
	1973 ¹	1974 ¹	1974 ²	1974 ³
CONTROL	68.5	21.8	43.7	21.3
8" H ₂ O	75.2	8.5	12.1	23.0
4" WHEY	168.8	50.8	86.6	77.9
8" WHEY	178.3	66.6	65.5	73.1
16" WHEY	156.7	71.7	39.1	7.9

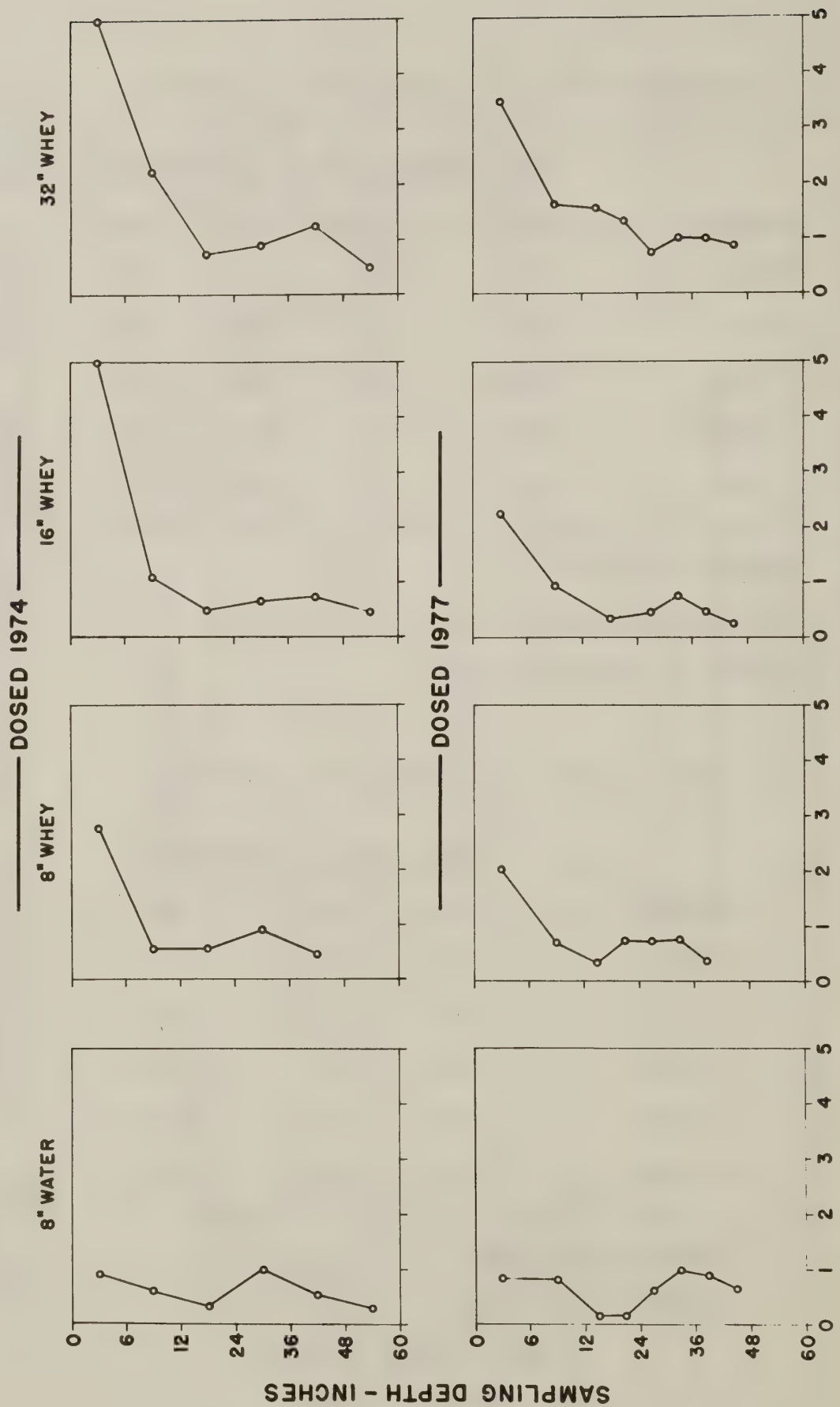
¹TREATED IN 1972 only²TREATED IN 1973 only³TREATED IN BOTH 1972 and 1973

TABLE IX.--Hay yields from whey treated plots

TREATMENT	YIELD, TONS/ACRE DRY MATTER		
	1973	1974 ¹	1974 ²
CONTROL	2.80	2.16	2.76
8" H ₂ O	2.37	2.43	2.44
4" WHEY	4.09	4.27	4.42
8" WHEY	3.82	4.58	4.53
16" WHEY	3.36	4.61	3.83

¹TREATED IN 1972 only²TREATED IN 1973 only

WHEY SPREADING AND PHOSPHORUS IN FALLOW SOIL

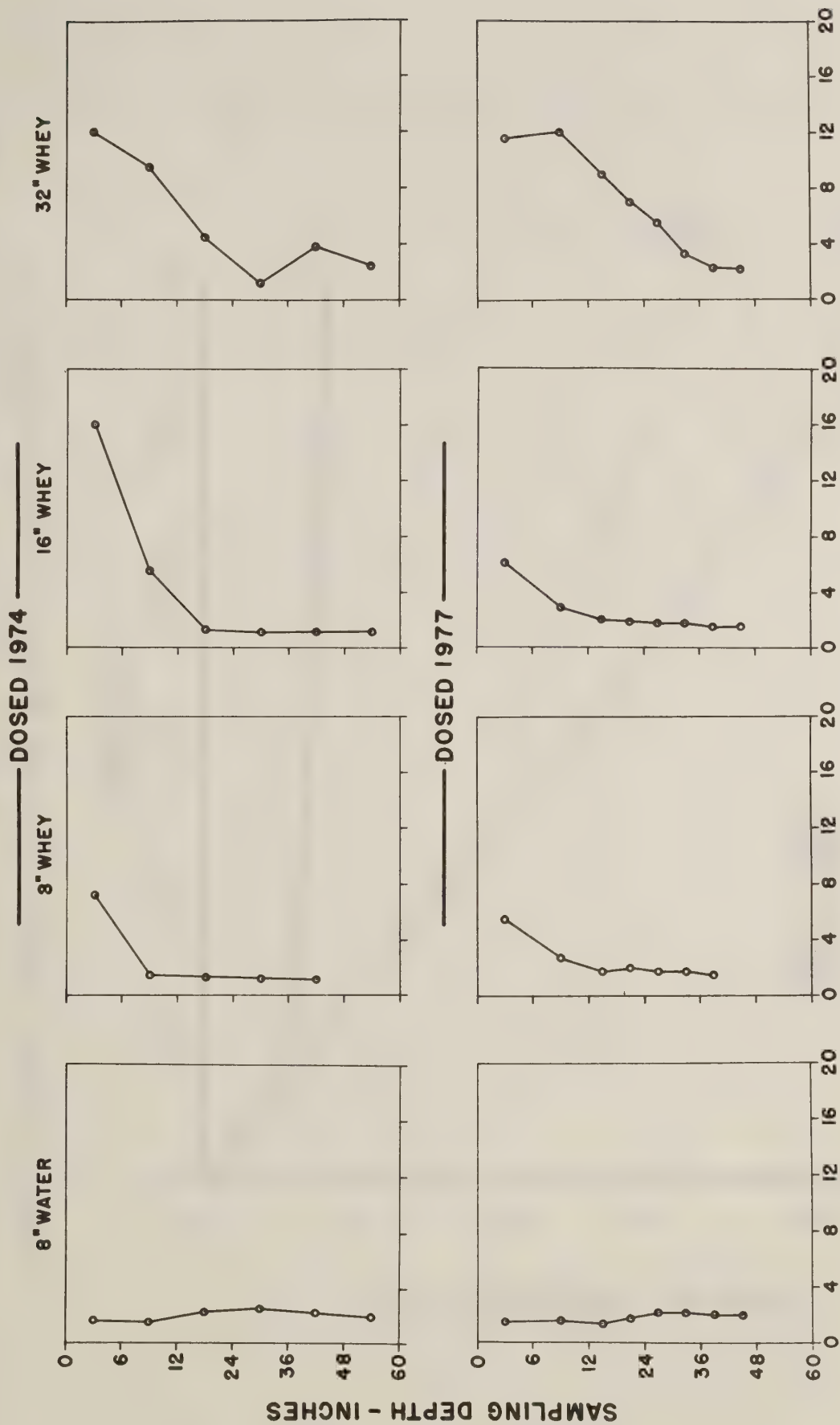


PHOSPHORUS PER ACRE - LBS. IN HUNDREDS

ARLINGTON EXPERIMENTAL FARM, UNIVERSITY OF WISCONSIN

Figure 7

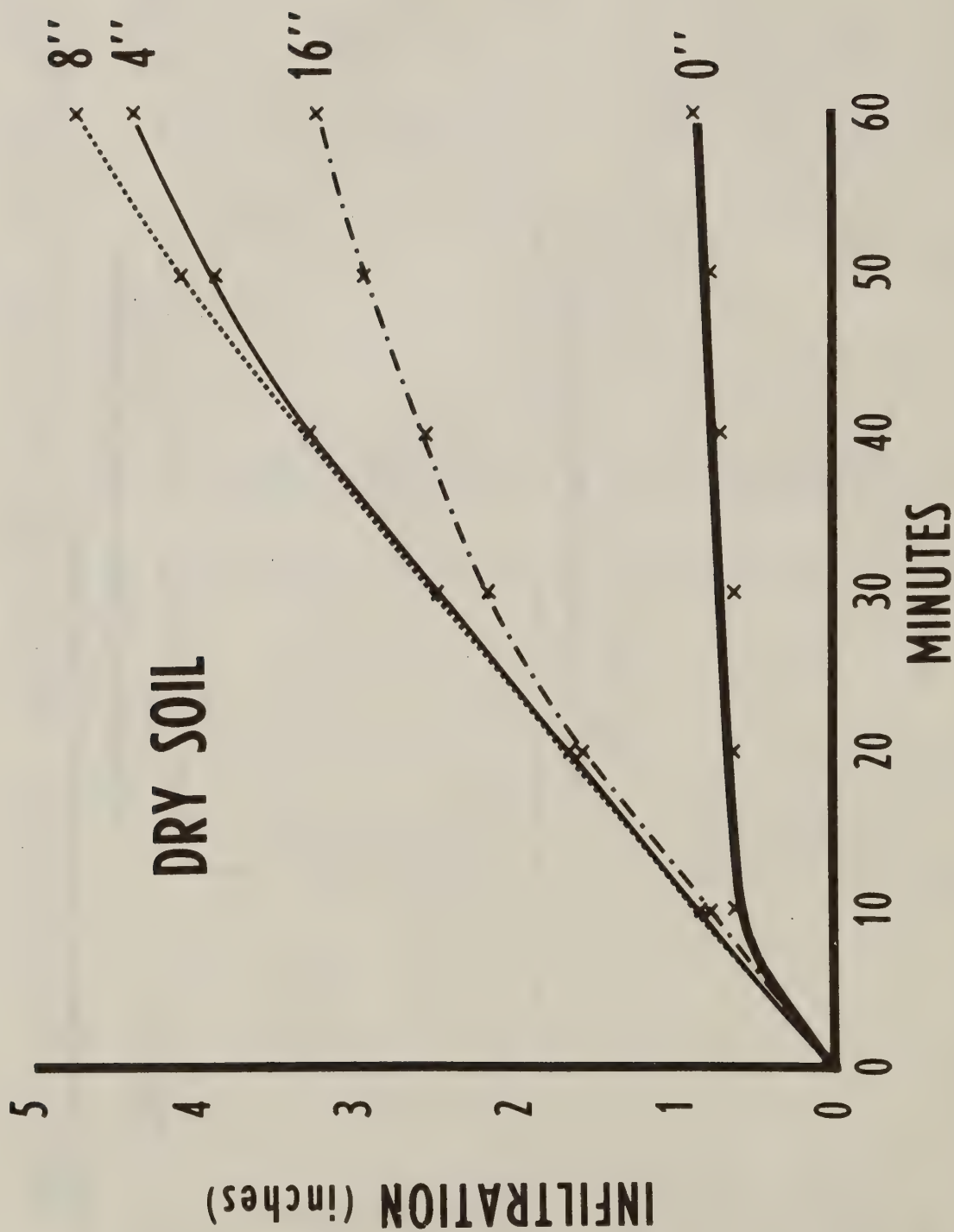
WHEY SPREADING AND POTASSIUM IN FALLOW SOIL



POTASSIUM PER ACRE - LBS. IN HUNDREDS

ARLINGTON EXPERIMENTAL FARM, UNIVERSITY OF WISCONSIN

Figure 8



Effect of Whey Applications on Water Infiltration Rates on fallow prairie soil, Univ. of Wis. Arlington Experimental Farm, 1972.

Figure 9

TABLE X.--Average corn yields (BU/A at 15.5% moisture)
from whey treated plots 1973, 1974

Year	Inches ¹ of Whey Applied				
	0	4	8	16	32
1975	60.3	131.9	152.8	138.5	40.1
1976	24.5	41.9	58.1	71.5	72.0
1977 ²	35.4	71.8	135.6	137.1	165.8
AVERAGE	43.7	95.9	120.4	109.3	63.4

¹One acre inch is approximately 28,000 gals.

²200 lbs. of 6-24-24 starter fertilizer drilled at
planting on all plots.

1. About 1 inch of whey applied annually will supply the balanced fertilizer nutrients required to keep a field in sound corn production. If excess whey is available, up to 4 inches can be applied without creating problems for the land or crop. The whey should be applied in 0.5-inch increments to control ponding or run-off tendencies.

2. A plant producing whey can work out a mutually beneficial arrangement with the farmers of the area to have its whey spread on this neighboring land. This can be done through the use of a tank truck with a splash plate driving along parallel routes until a field is adequately covered.

3. A storage lagoon or tank needs to be provided to impound the whey during extremely inclement weather so it can be spread after the weather improves.

4. The application of whey improves the permeability of the soil. This results in reduced run-off and soil erosion and makes the water retained available for future use by the crop.

5. By use of guidelines which have been developed, whey can be land-spread without creating water pollution problems.

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- (4) Watson, K. S., Peterson, A. E., and Powell, R. D., "Benefits of Spreading Whey on Agricultural Land," Journal Water Pollution Control Federation, Vol. 24, 1977.
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A LACTOSYLUREA WHEY PRODUCT FOR FEEDING TO RUMINANTS

Stig Widell
Astra-Ewos AB

Lactosylurea is formed by a chemical linkage between lactose and urea (Figure 1). This is a condensation reaction and shows that water is set free. Even if lactosylurea as such is a known compound, the way of application for admixturing in feed to ruminants has not been tested previously. What makes lactosylurea interesting from a nutritional point of view is that the energy source lactose really forms a chemical compound with the nitrogen source urea.

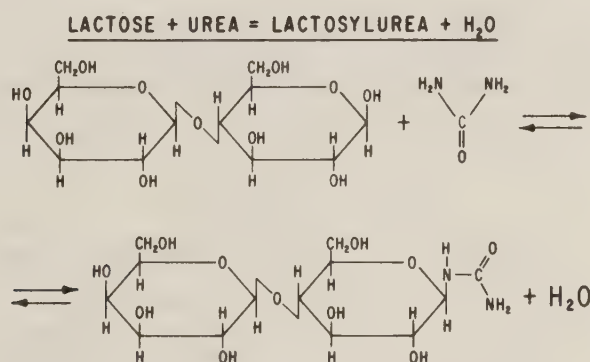


Figure 1

What is the advantage of this? Figure 2 shows that degradation of lactosylurea is much slower in cow rumen liquor (*in vitro*) compared with a mechanical mixture of lactose and urea. In the same way Figure 3 shows that the release of ammonia is considerably lower from lactosylurea than from urea in the mechanical mixture of lactose and urea. In cow rumen liquor there normally exist the urea enzymes which rapidly decompose urea into ammonia. Ureas, on the other hand, have no effect on the urea part in lactosylurea, which gives a considerably slower effect on release of ammonia. A heavy ammonia production may result in less utilization of the nitrogen and, if the concentration of ammonia in the cow rumen is too high, toxic symptoms may occur. Consequently, a rapid and heavy release of ammonia in the rumen should be avoided.

To enable the microorganisms in the rumen to synthesize microbe protein from the nitrogen in urea, easily available energy must be present during the process. By a chemical bond between energy in the form of lactose and the urea molecule, a synchronized release of energy occurs simultaneously as ammonia is available for microbe protein synthesis. In the manufacture of

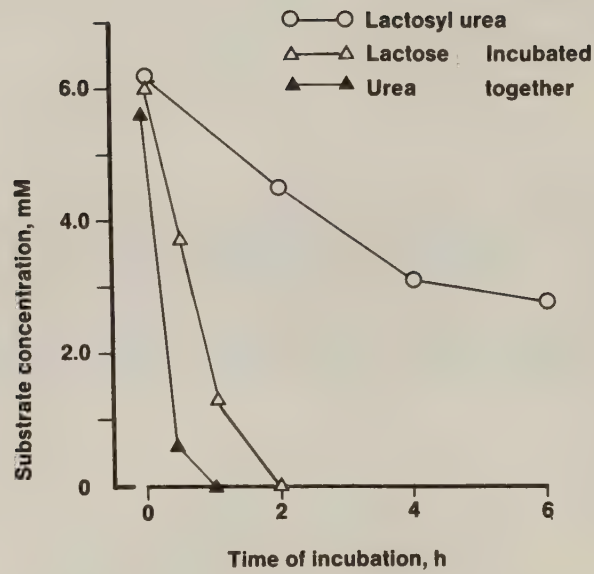


Figure 2

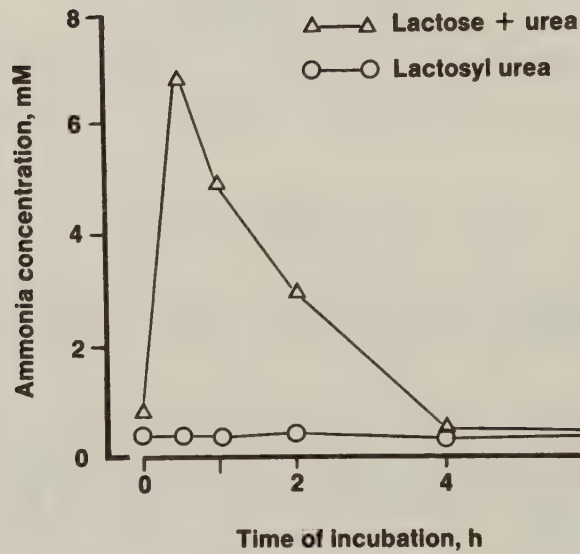


Figure 3

lactosylurea a suitable lactose source has to be found. Above all we have been working with whey and our whey product containing lactosylurea is called Ewoplus. Table I shows the different parts of Ewoplus. Apart from lactosylurea, we find the usual proteins in whey. We find minor parts of non-reacted lactose, minor parts of non-reacted urea and salts.

Table I.--What is EWOPPLUS?

Whey in REACTION with urea gives a mixture of:

Lactosylurea

Whey protein

Non-reacted lactose (minor parts)

Non-reacted urea (minor parts)

Salts

Figure 4 shows production and use of lactosylurea. The whey can be used as it is with a dm-content of 6% according to alternative I, the whey can be evaporated to varying dm-contents as in alternative II, or the whey permeate obtained after ultrafiltration according to alternative III can be used. The

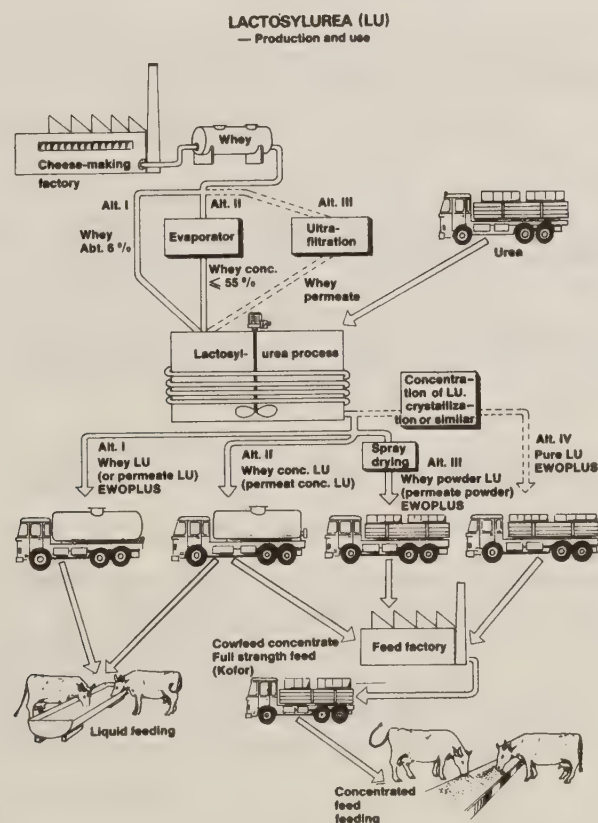


Figure 4

composition of the final product depends on the type of whey used. With liquid whey a low viscous product according to alternative I results, and it can be used only for liquid feeding systems. When the whey is evaporated, a high viscous liquid results. When whey concentrate with a high dm-content is used, a final product is obtained which can be used either in liquid feeding systems or included as an ingredient of concentrate during feed manufacture. After passing through the lactosylurea process, the product can be spray dried to produce a whey powder-lactosylurea product. It is also technically possible to crystallize the pure compound, lactosylurea. However, this is an unrealistic alternative from a commercial point of view.

Ewoplus has the following advantages:

Table II.--Advantages with Ewoplus (Lactosylurea-LU)

Lower toxicity (compared with other NPN-products) because of:

Slow release effect of LU (due to linkage) gives lower amount of ammonia in the rumen.

Better feed intake (compared with other NPN-products) because of:

Better palatability of the NPN-product

Lower plasma-ammonia improves acceptance to NPN-products (?)

Better utilization (compared with lactose and urea) because of:

Slower degradation of the lactose-part (due to linkage) which increases the utilization of this lactose (and the urea part as well) (?)

Slower degradation of urea (due to linkage)

Trials have shown that a cow without clinical symptoms can consume amounts of urea in the form of lactosylurea which, if it had been pure urea, would have caused death. Palatability trials have shown that this whey/lactosylurea product has a very good palatability in liquid form as well as mixed in concentrate. Better utilization still remains to be proved in trials. Apart from these nutritional aspects, the technical advantages are shown in Table III.

As the lactose in whey is linked to urea, problems with crystallization are avoided. Therefore, Ewoplus can be stored and transported with a higher dm-content than traditional whey concentrate (30-35%) without crystallization problems.

Table III.--Advantages with Ewoplus (Lactosylurea-LU)

Better handling properties (compared with whey) because of:

Better storage (no crystallization)

Cheaper transport (higher dm-content)

Improvement of pelleting properties (compared with no admixturing of Ewoplus) because of:

Harder pellets

Less energy needed

Improves the value of whey - increases possibilities for supplementation to ruminant feed - reduces the whey surplus

In pelleting trials, we have seen that Ewoplus gives harder pellets and the actual pelleting process requires less energy.

Apart from these advantages, whey in this process is upgraded, which also improves the possibility of admixturing of whey in feed to ruminants and thus the whey surplus can be reduced.

As shown in Tables IV-VI, extensive development work is going on. The idea to use lactosylurea as a nitrogen source in feed to ruminants originates from the U.K. (R. H. Smith and co-workers at the National Institute for Research in Dairying, Reading). NIRD workers had an early interest in optimising the different process variables. This work has also been followed up by our company in cooperation with the Swedish Dairy Association.

Table IV.--EWOPLUS - Product development programme

Technical aspects	Going on	Completed
Process optimising		X
Analytical technique		X
Identification methods of the LU compound		X
Scaling up production (5 ton batches)		X

Table IV.--EWOPLUS - Product development programme (Cont.)

Technical aspects	Going on	Completed
Different lactose sources		X
Pure lactose		
Whey		
Whey permeate		
Lactose reduced whey		
Spray drying the product	X	
Storage and stability tests	X	
EWOPLUS		
EWOPLUS in feed (mixture)		

Table V.--EWOPLUS - Product development programme

Nutritional aspects	Going on	Completed
"Urea" degradation - ammonia production		
<u>In vitro</u> (artificial rumen)	X	
NIRD		
SUA		
<u>In vivo</u> (cows and sheep)	X	
NIRD		
SUA		
Toxicity to ruminants		X

Table V.--EWOPLUS - Product development programme (Cont.)

Nutritional aspects	Going on	Completed
Microbe protein synthesis (utilization of LU)	X	
<u>In vitro</u>		
NIRD		
DUA		
SUA		
<u>In vivo ?</u>		
NIRD		
DUA		
Palatability trials		X
Mixed into feed		
Liquid feeding (ad lib)		
Milk production trials	X	
NUA		
SUA		
Beef production trials	X	
NUA		
SUA		
Metabolite studies of LU	X	
C ¹⁴		
N ¹⁵		

Table VI.--Substitution with EWOPUS

ALT. I.

Ground shelled corn + Soy/Starea = Ewoplus Conc.			
Crude prot. %	10.0	44.0	28.0
Substitution, %	47.0	53.0	100.0

ALT. II

Rolled barley + Soy/Starea = Ewoplus Conc.			
Crude prot. %	11.0	44.0	28.0
Substitution, %	48.5	51.5	100.0

Production of Ewoplus is scaled up to 5-7 ton batches. In our laboratory we have been working with lactose sources other than whey. Originally we started with pure lactose, but we have also tried, with good results, whey permeate and whey remaining after lactose crystallization. However, such whey still contains considerable quantities of lactose, but this raw material can be used.

Storage tests are being made and the results so far indicate that Ewoplus as such can be stored for an unlimited time, but the concentrate containing Ewoplus is subject to the same risk of moulding as traditional concentrate.

In vitro and in vivo trials, where the degradation of urea in lactosylurea and production of ammonia, respectively, are shown, are at present being conducted in England and in Sweden (the Swedish University of Agriculture). At the Swedish University of Agriculture tests have shown that lactosylurea has a very low toxicity to ruminants. An important part in the documentation are the studies of microbe protein synthesis to show that urea in a compound with lactose results in better utilization compared with mechanical mixture of lactose and urea. Such trials are being conducted in England, Sweden (the Swedish University of Agriculture) and Denmark (the Danish University of Agriculture). Trials in vivo are planned as well. Regarding feed trials, both palatability trials and milk production trials in Sweden and Norway are going on. The Swedish trials have been carried out during the whole lactation period. The intention with these trials is to show that lactosylurea can substitute for other NPN-compounds as well as traditional vegetable protein sources with good results. Also meat production trials, with soy and Starea substituted with Ewoplus, are going on in Norway and Sweden. According to plans, present production trials on milk and meat will be completed at the turn of the year 78-79.

Ongoing metabolite studies with the lactosylurea compound marked by isotopes hopefully will show in detail how lactosylurea is metabolised in the cow rumen. Both C₁₄ and N₁₅ have been used.

Calculation of substitution can be made as shown in Table VI. For example, 47% ground shelled corn and 53% soy can be substituted with 100% Ewoplus concentrate; in alternative II, 48.5% barley and 51.5% soy or Starea can be substituted with 100% Ewoplus concentrate. Therefore, 1 kg Ewoplus concentrate is, from a nutritional point of view, equivalent to 485 g barley and 515 g soy/Starea.

Dr. T. C. Everson
Wisconsin Dairies Cooperative, Inc.

INTRODUCTION

Henry Ford was asked what our country would do when gasoline for his Model A's ran out. His reply was, "We'll make fuel from whatever grows at the side of the road." Alexander Graham Bell answered the same question in 1917, "Burn alcohol. Alcohol makes a beautifully clean and efficient fuel. We can make alcohol from sawdust, the waste product of our mills, from cornstalks, and, in fact, almost any vegetable matter capable of fermentation."

During WWII, the German Wehrmacht managed to keep going by using alcohol fuels made from potatoes. More recently, Brazil has 7 million cars now running on a blend of 20% alcohol and 80% gasoline. The alcohol comes from sugar cane fermentation.

Gasohol is defined as a blend of unleaded gasoline and ethanol in various combinations. The most common blend sold in the U.S. is 90% unleaded gasoline and 10% ethanol.

As long as petroleum was cheap (at \$2 a barrel), fermentation derived ethanol as a fuel was not a reality; however, at \$12.40 and increases of 75-100% projected for the near future, ethanol and methanol fuels could become a factor in our energy program.

One of the most controversial figures in the gasohol debate, is Dr. William A. Scheller, head of the Department of Chemical Engineering at the University of Nebraska. He states that, from an economic and energy point of view, gasohol makes a lot of sense.

Scheller claims that from a free energy standpoint, production of ethanol from grain through fermentation yields a positive energy balance. His opponents claim the opposite: a huge loss of energy in the fermentation process.

The big difference in energy calculations comes from the following factors: 1) Scheller draws an energy boundary around the ethanol plant and the farm, whereas his opponents consider the plant process alone; 2) Scheller assumes that energy can be obtained from burning the cornstalks, cobs, and husks as fuel in the plant; 3) Scheller states that the by-product of the fermentation, distillers' grain, provides a better feed additive than feeding corn, with a savings in energy; and 4) Scheller takes credit for improved octane and better gas mileage.

In summary, Scheller says that producing 10 gallons of gasohol or one gallon of ethanol saves the equivalent of 1.81 gallon of imported crude oil. In its place we need to burn the equivalent of 1.12 pounds of coal. Since coal is a domestic product, an improvement in the U.S. trade balance would

result.

Scheller's economic calculations look equally as good as his free energy data. A 20-million-gallon ethanol plant, with milo (sorghum) used as feed would cost \$27 million, which includes \$4 million working capital. Annual income would be \$31.3 million, assuming a selling price of \$1.10/gallon of ethanol, distillers' dry grain at 6¢/pound, and carbon dioxide at a 0.1¢/pound. Purchasing milo at \$3.50/cwt and estimating conversion costs at 30¢/gal., an annual expense would be \$21.4 million after allowing for depreciation and taxes. The alcohol plant would show a net profit of \$3.8 million and a net cash flow of \$6.1 million or 22.7% of investment.

However, the skeptics, such as Mr. Cloud Cray, president of Midwest Solvents, state that gasohol makes no economic sense in the U.S. as long as less expensive fossil fuels are available. Cray operates an ethanol grain fermentation plant in Atchison, Kansas. He states that the actual production costs for ethanol are 98¢/gallon without a profit calculated. This cost is considerably higher than Scheller's estimated 74¢ cost for the hypothetical fermentation process.

Other skeptics include the USDA, which concludes in its report "Gasohol from Grain-The Economic Issues," that a national gasohol program of 10 billion gallons of ethanol blended with 90 billion gallons of unleaded gasoline would require a subsidy of 10.4¢/gallon of gasohol. That's \$10.4 billion annually.

USDA states that, for each BTU invested in growing and processing corn, only 0.5 to 0.8 BTU is recovered in the ethanol. Grain production would have to rise substantially, with some acreage directed from soybeans and wheat. Prices of food and feed grains would rise sharply.

USDA warns that 70 billion pounds of by-product, distillers' dried grain, would depress soybean oil meal prices. The soybean crushing industry would be nearly eliminated. The only markets left for soybeans would be food grade oil and export markets. USDA believes that livestock production would drop and consumer food prices would increase. Therefore, the entire fermentation question must be examined in light of all the consequences.

Since a gallon of unleaded gasoline contains 135,000 BTU's and costs \$0.38 and ethanol only 85,000 BTU's and costs \$1.25-\$1.30, ethanol is five times more expensive than gasoline. The skeptics say that it's too expensive to manufacture gasohol as long as less expensive fossil fuels still exist.

However, several states, such as Nebraska, have instituted a 5¢/gallon tax credit on each gallon of gasohol produced. Congress is pressing the USDA to release the \$60 million it has allocated in a federal loan guarantee program to investigate production of ethanol from grain.

Other bills are pouring into the Congressional hopper. Most of them provide subsidies in the form of exemption from federal gasoline tax or by allowing five-year plant amortization schedules.

Senator Bayh's bill would make gasohol sales mandatory starting with 1% ethanol content in 1981 and rising to 10% by 1990. Senator Percy wants a federal gasohol test fleet. Congress wants action from the Department of Energy rather than more studies.

With this information as a backdrop, we should now examine the methods of production of ethanol from whey, along with the economics of fermentation of whey to ethanol and yeast single cell protein.

Possible routes to gasohol production are shown in Figure 1. Many processes for fermentation of whey have been developed in the past. The references at the end of the paper trace the development of technology on this subject.

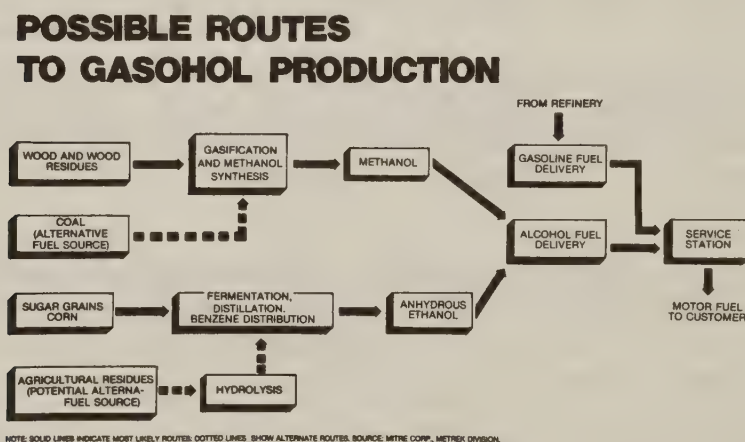


Figure 1

The manufacture of ethanol from whey is accomplished through yeast fermentation of lactose to pyruvic acid, acetaldehyde, ethyl alcohol, and carbon dioxide (Figure 2).

Kluyveromyces fragilis and Torula cremoris are the most common organisms used for producing ethanol and yeast from whey. These yeasts have a faster fermentation rate and produce the highest yields of ethanol compared to other yeast cultures.

In early work in this area, Myers and Weisberg found K. fragilis suitable for use in the manufacture of delactosed whey. Ethanol was a by-product of the manufacture and not considered to be of economic importance. The delactosed whey found use as an excellent quality, animal feed supplement owing

to the high concentrations of albumin, globulin and minerals from the whey, as well as vitamins contained in the yeast cells.

PRODUCTS OF YEAST FERMENTATION OF LACTOSE

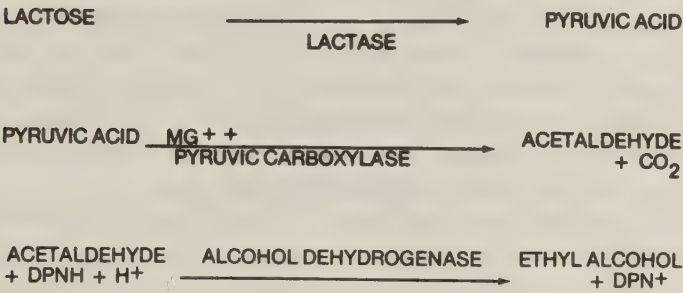


Figure 2

Research workers through the years have perfected the fermentation process of whey to valuable single cell protein and ethanol. The fermentation process for production of delactosed whey and ethanol from whey follows the general format as given in Figure 3.

PRODUCTION OF DELACTOSED WHEY AND ETHYL ALCOHOL FROM WHEY

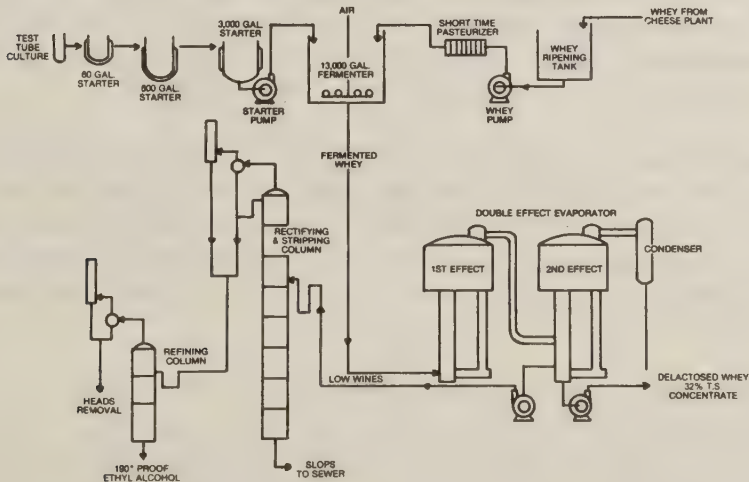


Figure 3

The yeast used for the fermentation process can be carried as stock cultures on slants of whey agar. After incubation at 30°C for 2 days, the slants should be refrigerated between transfers. The culture to be used for fermenting the main batch of whey is built up through a series of transfers in pasteurized or sterile whey. Each batch of whey for a given starter culture is inoculated with 10% of the previous whey culture.

The whey used for the starter and main batch is "ripened" in order to develop a titratable acidity of about 0.5% lactic acid, which is favorable to the yeast and unfavorable to contaminants. As cheese whey is normally the type available for such processes, usually sufficient lactic acid streptococci and lactobacilli are present to develop the desired acidity without having to add any inoculum at this point. After the "ripening" process, the whey is given a high-temperature short-time pasteurization. This step is desirable to destroy the lactic-acid-producing bacteria and to prevent further conversion of the lactose to acid. The whey is cooled to 30°C and piped to the fermentor for inoculation with 10% yeast starter.

The inoculated whey is aerated with filtered, cool air, and the lactose is usually completely fermented in 14-20 hours. The activity of the starter, quality of the whey, temperature, and other factors determine the fermentation time required for each batch.

A reducing sugar test is employed to determine when the lactose has been exhausted from the fermentation mash. The yield of ethanol from the lactose will be greater if no aeration is used during the fermentation. However, aeration accelerates the rate of fermentation and therefore lessens the time necessary for complete fermentation of the lactose. The yeast crop is also lowered with reduced aeration, and nonfermentation carbohydrates accumulate. The main contaminants that should be eliminated from the fermentation are lactic acid and acetic-acid-producing organisms, which reduce the yield of ethanol.

The fermented whey is condensed to about 32% and dried in a conventional spray dryer. The condensates contain 4-6% ethanol and are collected as "low wines." The low wines are then treated in a rectifying and stripping column and finally in a refining column to produce 95% ethanol.

A process that makes use of modern fermentation technology and equipment to convert the lactose of whey to single cell protein and ethanol was developed in 1972 by Milbrew Inc., Juneau, WI. Under a research grant from the Office of Research and Development, U.S. Environmental Protection Agency, Milbrew developed a much more efficient process of yeast fermentation of whey than shown in Figure 3.

Yields of single cell protein and ethanol are reported to be higher than literature values because of a unique fermentation design. In general the process is as follows: The organism used was Kluyveromyces fragilis, NURL Y1109. Inoculum buildup was accomplished by transfer from stock slant to shake-flasks to 10 liters in a 14 liter New Brunswick fermentor, then to 60 gallons, and finally to 300 gallons in a 500 gallon seed fermentor.

Whey, either acid or sweet, is obtained in concentrated form of 45-50% solids. The whey is diluted to 10-15% solids with water, raw whey, or condensate water from the evaporator. The other ingredients such as anhydrous ammonia, hydrochloric acid, yeast extract, and phosphoric acid are added. The pH is controlled automatically by acid or ammonia additions to 4.5. The medium is heated to 80°C, held for 45 minutes and cooled to 30-33°C for fermentation. The fermentation is carried out in a 15,000 gallon stainless steel storage tank that has been modified with air sparger and fully baffled agitator. Automatic instrumentation controls pH at 4.5, temperature at 30-33°C, aeration at 1.0 ± 0.2 volume of air per volume medium per minute. Foaming is controlled by automatic addition of defoamer, and level controls maintain the fermentation at 60-70% of capacity in tank.

The fermentor may be operated in a batch, semicontinuous, or continuous manner. After fermentation the fermented whey mass is collected and spray dried. The ethanol is collected at levels of 4-9% v/v from the evaporator and piped to the ethanol recovery plant. Condensate water from the ethanol recovery plant is returned to dilute condensed whey, thus maintaining a "closed-loop" cycle with no effluent streams to dispose of.

In a batch fermentation, starting with a seed having a viable cell count of 1×10^9 cells/ml and an inoculum of 10%, all of the lactose is utilized in 8 hr., with an increase in cell concentration of 10-20 fold. This cell increase represents a generation time of approximately 2.0 hrs. and four doublings within an 8 hour period.

Figure 5 shows the cell count increase and lactose concentration decrease for the fermentation process in semi-continuous operation. This process was performed by draining off 90% of the fermentation batch. The only downtime experienced is the time necessary to pump off the 90% of fermented broth and pump in the fresh medium.

The downtime can be eliminated if the fermentation can be run continuously, for example, with continuous addition of fresh medium and removal of the fermented mass (Figure 6). The continuous fermentation is begun when the cell count of the broth reaches 1×10^9 cells/ml and the lactose concentration drops to 0.5-0.7%. At this time, fresh medium is added and the fermented mash is removed at an equal rate. The fermentor can be operated in this manner for 2-3 weeks of continuous operation. No change in cell count or buildup of contaminants or metabolic products that would interfere with the fermentation process was evident. With a fresh medium inoculum and fermented mash removal of 1,250 gallons per hour, a fermentation cycle of 10,000 gallons per 8 hours is obtained.

Since the primary emphasis of this process is to obtain single cell protein without process effluents, the "closed-loop" system of operation is used (Figure 7). If the yeast cells are harvested by centrifugation and washed, a food grade, primary yeast is obtained. However, waste streams that require primary and secondary treatment to eliminate the pollution load are produced also.

PLOT OF SEMI-CONTINUOUS FERMENTATION-MILBREW PROCESS

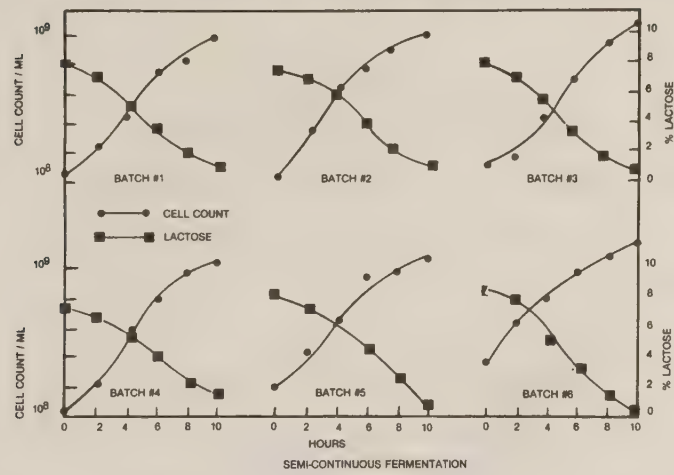


Figure 5

PLOT OF CONTINUOUS FERMENTATION IN 15,000 GALLON FERMENTOR-MILBREW PROCESS

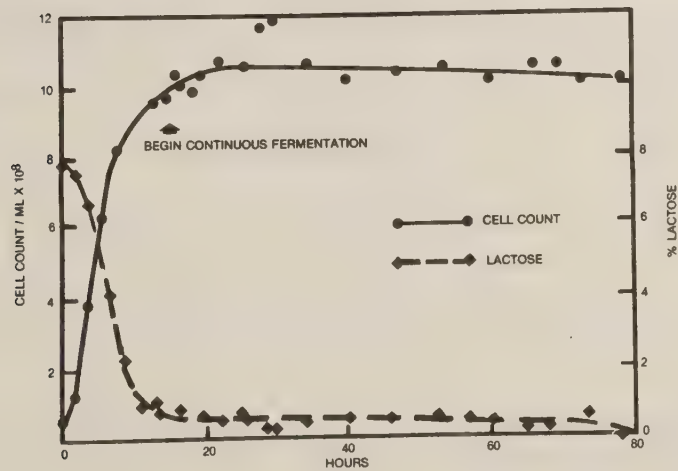


Figure 6

CLOSED-LOOP SYSTEM FOR FERMENTATION WITH ZERO EFFLUENTS MILBREW PROCESS

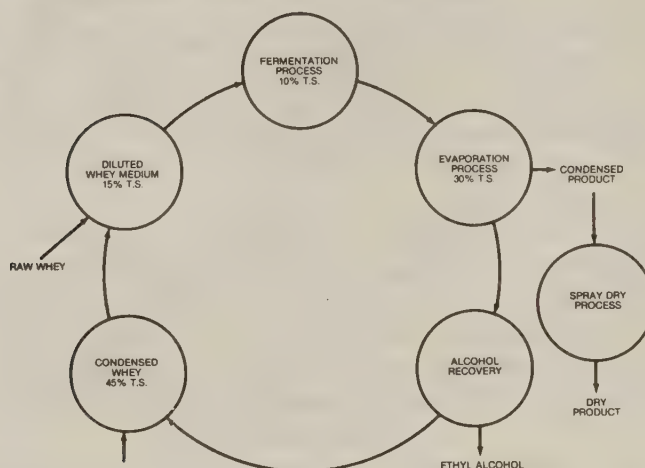


Figure 7

The proximate analysis, protein efficiency ratio, and quality of the protein are shown in Tables I, II and III. During the fermentation, ethanol

TABLE I.--Proximate analysis of fermented whey products

CONSTITUENT	YEAST FERM. SOL. AMBER YFS (%)	CENT. YEAST AMBER NUTREX (%)
Crude Protein	35-50	45-55
Ash	12-20	6-10
Fat	2-3	2
Moisture	3-4	3-4

TABLE II.--Protein efficiency ratio (per) assays
of fermented whey products

PRODUCT	AVERAGE VALUE 4 WEEK STUDY	% OF ANRC CASEIN
Amber YFS	1.72	69
Amber Nutrex	2.26	91
ANRC Casein	2.50	100

TABLE III.--Amino acid content of various single-cell
proteins compared to FAO profile

AMINO ACID	% OF TOTAL PROTEIN					
	FAO PROFILE	AMBER NUTREX	BREWERS YEAST	TORULA YEAST	BRIT. PET. YEAST	AMOCO YEAST
Lysine	4.2	6.9	6.8	8.5	7.5	6.6
Methionine	2.2	1.6	1.5	1.5	1.8	1.4
Valine	4.2	5.4	4.7	5.6	5.8	5.7
Leucine	4.8	7.0	5.8	8.0	7.8	7.1
Isoleucine	4.2	4.0	3.6	6.4	5.3	4.5
Tyrosine	2.8	2.5	2.7	4.3	3.6	3.3
Phenylalanine	2.8	3.4	3.4	5.1	4.3	4.1
Tryptophan	1.4	1.4	1.1	-	1.4	1.2
Histidine	-	2.1	2.1	2.2	2.1	2.1
Threonine	2.8	5.8	5.9	5.1	4.9	5.5

is produced. Changing the conditions of fermentation, such as operating under anaerobic conditions, 0.1-0.3 volume of air per volume of medium per min. can increase the amount of ethanol. The results shown in Figure 8 are for a typical batch of whey in the 15,000 gallon fermentor. After an initial period of aerobic operation to buildup cell concentration, the mash was "spiked" with additional lactose and fermented under anaerobic conditions. The lactose was

utilized at a continuous steady rate. The cell population no longer increased, but remained at a constant level. When condensed whey was added incrementally, ethanol was produced in larger amounts with yields as high as 90%. The balance of the lactose was metabolized for cell maintenance. The production of slightly over 9% ethanol in this manner was possible.

ETHANOL PRODUCTION BY ANAEROBIC FERMENTATION- MILBREW PROCESS

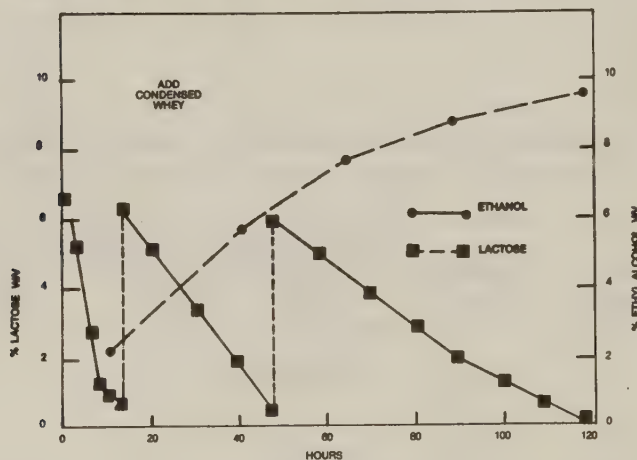


Figure 8

Milbrew is the only plant in the U.S. making commercial size quantities of yeast and ethanol from whey. The Milbrew plant at Juneau, Wisconsin, operated its yeast and ethanol plant in a continuous manner for the purposes of the EPA study in 1974-75. The annual production rate was 4,000,000#s of yeast fermentation solids, which represented a use of approximately 100 million pounds of raw whey per year. The total mass balance for the production of yeast fermentation solids and ethanol is given in Table IV. The assumptions made are that liquid whey contains 6.5% total solids, and the fermentation was aerobic to maximize production of single cell protein (YFS).

The costs of production are controlled mainly by the price of the whey substrate (Table V). Milbrew, Inc., assumed that the whey could be obtained at no cost or the cost of evaporation or transportation or both. Therefore, the whey substrate costs were zero to 4.5 cents per pound of finished product.

The cost of production is also affected by the size of operation. Labor and other costs decrease per pound of finished product as the size of equipment and its degrees of automation and sophistication increase. However, as

TABLE IV.--Total mass balance

MATERIAL	AMOUNT (#/DAY)
Input Material:	
Whey Solids*	30,600
Water*	220,248
Salts, acid, vitamins	1,560
Ammonia (NH ₃)	1,320
O ₂ from air	<u>1,272</u>
Total	255,000
Output Material:	
YFS Solids	21,432
Water	220,248
Ethyl Alcohol (ETOH)	5,088
CO ₂	<u>8,232</u>
Total	255,000

*Source of whey solids and water is either 39,864 lb. condensed whey + 210,984 lb. raw whey or 68,000 lb. condensed whey + 182,848 lb. water.

TABLE V.--Calculated productions costs for dried yeast fermentation solubles from whey fermentation (1974-75)

ITEM	¢/# OF PRODUCT
Medium	0-4.5
Operating Utilities:	
Evaporation and drying	1.45
Aeration, cooling	1.00
Other	.40
Labor	2.40
Capital investment	2.05-4.0
Overhead	2.40
Total	11.8-16.5

the capacity increases so does the capital investment and connected charges for depreciation, taxes, insurance, and physical facilities. A plant capable of an annual production of 8 million to 20 million pounds of YFS per year would cost about \$6-\$15 million. This size plant is considered small compared to plants being planned to produce single cell protein from hydrocarbons with a capacity of 200 million pounds per year.

For a plant producing 8-20 million #s of YFS per year, production costs of 11.8 to 16 cents per pound were obtained. These costs were calculated in 1974-75 and would naturally have to be increased for 1978-79.

During the time of the study the actual production cost averaged 15.4¢/# of YFS material produced. Sales of this material were made at 18 to 24¢/#.

With varying conditions of fermentation, increased amounts of ethanol can be produced and recovered but at the expense of cell yield. Humphrey concluded in 1974 that "Energy considerations could also affect the type of single cell protein (SCP) process. Aeration costs could become higher as energy costs continue to rise. Hence, an anaerobic fermentation, in which both ethanol and SCP feed are produced could be the process of choice."

A comparison of the economics of whey fermentation was made assuming that the fermentation plant was adjacent to the cheese plants, and a total of 30,600#s of whey solids was processed daily (Table VI). Estimates for the costs of production under aerobic and anaerobic conditions were made.

The gross returns were calculated based on the use of ethanol at 200 proof and \$1.35/gallon, and YFS solids at 21¢/# selling price and 15¢/# production costs.

These were compared to drying whey, with sales at 15¢/# and processing costs of 7¢/# giving a gross margin of 8¢/# or 44¢ per hundred weight (cwt) of liquid whey.

The results indicate that the fermentation process would not be more desirable than simple drying of whey since the gross margin of each equalled about 50¢/cwt of liquid whey. In fact, a margin 15¢/cwt lower than that obtained with the making of spray dried whey could be expected if aerobic conditions were employed in the fermentation process.

Several other companies have fermented whey for production of yeast or ethanol. The Knudsen Corporation operated a small fermentation plant for acid whey conversion to yeast in California up to three years ago. The whey from the cottage cheese plant is now contracted to Stauffer Chemical Company for processing by ultrafiltration.

The Kraft Corporation at Stockton, IL, processed whey by yeast fermentation to obtain ethanol and a delactosed whey feed ingredient until a few years ago. The ethanol was used as a starting material for vinegar production.

TABLE VI.--Comparison of gross margins for
whey fermentation vs spray dried whey

I. SPRAY DRIED WHEY		<u>\$/CWT WHEY</u>	
	Gross Return	.94	
	Cost of Production	<u>.44</u>	
	Gross Margin	<u>.50</u>	
II. WHEY FERMENTATION		<u>ALCOHOL</u>	<u>YFS</u>
A. Aerobic			
	Gross Return	.26	.92
	Cost of Production	<u>.17</u>	<u>.66</u>
	Gross Margin	<u>.09</u>	<u>.26</u>
B. Anaerobic		<u>ALCOHOL</u>	<u>YFS</u>
	Gross Return	.52	.82
	Cost of Production	<u>.24</u>	<u>.59</u>
	Gross Margin	<u>.28</u>	<u>.23</u>
Total Aerobic Ferm.		.35	
Total Anaerobic Ferm.		.51	

Walnack and Associates have reported that a plant similar to the Milbrew Juneau operation is under construction in Ireland to produce ethanol from whey lactose. In addition, the Dutch Institute for Dairy Research has announced its plans to use a process to manufacture protein concentrate by ultrafiltration with fermentation of the lactose "rich" permeate into ethanol.

A large reservoir of unprocessed whey exists in the U.S. Table VII shows the % of total whey solids manufactured in relation to the total whey solids available. In 1977, 46.8% of the U.S. production of liquid whey was not further processed or marketed. If all of this whey were available for fermentation, 50 million gallons of ethanol could be produced. Also 536-570 million pounds of yeast fermentation solubles would be produced as a by-product. It is likely that adding this quantity of yeast fermentation solubles to the feed market will lower the 31¢/# price substantially and greatly erode the gross margin of the process.

The production of 50 million gallons of ethanol would have little effect on alleviating the shortage of fossil fuels in the U.S., since 10 billion gallons are required for a mixture of 10 parts ethanol and 90 parts gasoline per year.

TABLE VII.--Percent of total whey solids processed compared to equivalent whey solids produced

DATE	TOTAL EQUIVALENT WHEY SOLIDS	TOTAL PROCESSED WHEY SOLIDS	% PROCESSED
	MILLIONS OF #s		
1972	1,830	973	53.2
1973	1,868	1,027	55.0
1974	1,987	1,123	56.5
1975	1,918	1,159	60.4
1976	2,219	1,214	54.7
1977*	2,239	1,192	53.2

* Pending revision

The total capital investment in fermentation plants would be very high and an estimate of 27, \$11 million plants would be needed or a total investment of \$297 million. Moreover, the majority of unprocessed whey solids would require collection and transportation to a centralized fermentation plant. The transportation of noncondensed whey could not be made over 100 miles or a significant loss in gross margin would result for the fermentation process.

The existing spray dried whey industry would not be induced to invest in fermentation equipment, since the present gross margins are too low for ethanol and dried yeast. However, new fermentation technology for single cell protein could reduce production costs through improved yields and shortened fermentation times. I will mention one process developed by Imperial Chemical Industries of Great Britain as an example.

The process makes use of a "pressure cycle fermentor" which optimizes the oxygen transfer rate to the bacterium or yeast cell. The savings occur in the amount of energy required for aeration and agitation.

It is only through additional technological "breakthroughs" in the fermentation industry that the use of whey-derived alcohol as motor fuels will become a reality.

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THE CONVERSION OF CHEESE WHEY

INTO AN ALCOHOLIC BEVERAGE

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Foremost Foods Company

INTRODUCTION

In 1976 the United States Department of Agriculture (USDA) reported production of nearly 37 billion pounds of whey in the United States as by-products of the manufacture of cottage cheese and of hard cheeses such as Cheddar, Swiss, Mozzarella, and Jack. Estimates were that 70 percent of that whey was processed into food, food ingredients, lactose or animal feed; but that 30 percent was not utilized.

That 30 percent - roughly 11 billion pounds of whey per year - became either an environmental pollutant, being sprayed onto wasteland or dumped into rivers and streams, or an added consumer cost, being cycled to municipal wastewater treatment systems for purification.

It is to the conversion of at least a portion of that unused whey to a useful and enjoyable product that this report speaks.

BACKGROUND

Much of the reason for the cited pollution from whey lies in the economics of collecting it from small and/or isolated sources for central manufacture into useful concentrated or dried products by whey processors. To circumvent those economics and to find a way to convert that whey into a useful and marketable product at its source, Oregon State University (OSU)--working under Environmental Protection Agency (EPA) Grant No. 803301--demonstrated the technical feasibility of fermenting supplemented whey into an alcoholic beverage. That grant was entitled "Utilization of Cheese Whey for Wine Production."

Based on the successful completion of that work, Foremost Foods Company was granted EPA Project No. S-8038-63010 entitled "A Demonstration Project on the Utilization of Cheese Whey for Wine Production."

OBJECTIVES

The primary objective of that project was to demonstrate commercial feasibility of producing an alcoholic beverage by wine yeast fermentation of sweet and acid cheese wheys, or supplemented wheys, followed by flavoring.

Subordinate objectives were:

1. To transfer the bench scale process developed by Oregon State University, with Cheddar cheese whey, to a pilot process making use of applicable dairy and cheese plant equipment and technology.

2. To adjust the pilot process to fermentation of cheese whey other than Cheddar, and to wheys deproteinized by membrane processing (ultrafiltration).
3. To adjust processing by use of other unit operations as time permitted and experience warranted.
4. To relate processing to final product by means of analytical and sensory testing.
5. To develop at least one flavored variant--with or without carbonation--and determine consumer acceptance, comparing it with a leading commercial flavored wine.
6. To develop process economics--projecting from pilot experience--to small-scale and large-scale operations.
7. To characterize process residues and recommend potential end uses.
8. To determine legal requirements to ferment alcoholic beverages in a dairy or cheese plant environment.

RESULTS

To meet the objectives, the Foremost Foods Company Research and Development Center developed processing to convert either sweet or acid wheys into an alcoholic beverage with little or no hint in its flavor as to its origin in whey. A natural fruit flavored beverage was developed from this base, and small-scale consumer testing demonstrated parity acceptance when compared to a market leader in the fruit flavored wine class. Preliminary process costs indicate that the beverage can be competitive in the market place. Materials balance studies demonstrated that the wastes from the fermentation process, measured in terms of COD, were on the order of 75-90% reduced from that which would have resulted from disposal of the whey without fermentation.

It was demonstrated early that sweet whey or acid whey yielded to processing in similar manner. Because the greater need for whey utilization was perceived to exist within the acid whey area, a major portion of our efforts was directed to acid whey; although, with nominal variation, the processing applies to sweet whey as well.

The processing from whey to a finished flavored product requires:

1. Clarification of the whey.
2. Deproteinization of the whey.
3. Supplementation to a fermentable medium.
4. Fermentation.

5. Clarification of the ferment.
6. Demineralization.
7. Formulation.
8. Polishing filtration.
9. Carbonation.

HISTORICAL

Before discussing our development studies and accomplishments, let me give you a brief historical picture of the bench scale work done at Oregon State University and the transfer of those results to Foremost.

The Enology Department at OSU had demonstrated that Cheddar cheese whey was a complete medium for growth and fermentation by several strains of wine yeast, provided a fermentable carbohydrate was added, the wine yeasts being unable to ferment the lactose in the whey.

OSU studies further demonstrated that the Montrachet strain of wine yeast was able to ferment supplemented and deproteinized whey to completion--about 10 percent alcohol--in seven to eight days at room temperature.

They had followed the fermentation with standard wine-making operations, including sedimentation of the yeast, addition of fining agents to clarify, and several rackings of the beverage to provide final clarity.

They had made several attempts to blend the whey wine with fruit wines to make a palatable beverage.

We were introduced to whey wine by sampling some of the products made at OSU prior to beginning our study. Suffice it to say that the native whey wines left much to be desired at the palate, and the blended wines--although better--still retained salty and whey notes which we judged were incompatible with a beverage concept. Although technically successful, the OSU study--based on our impressions of the resultant beverages--served to demonstrate that Foremost had a real challenge on its hands to develop a marketable product.

Instead of attacking the table wine market--which, incidentally, some of our California Congressmen thought we were doing at the news of our receiving the grant--we elected to set as our target a beverage to compete against the fruit flavored wines or the pop wines of commerce. One of the reasons for selecting the pop wine market as our target was the firm belief that, within the space of time and money available on this project, we had little chance of making an unflavored beverage of vintage quality from whey; another was that the flavored wine market was reportedly growing healthily; and yet another, we looked to the flavoring system as an aid to masking whey odors and flavors in the final product.

DISCUSSION

Now let me approach the discussion of process and product development with a constraint which was not formally stated, but which was taken into account as we made processing decisions throughout the study.

This constraint was that whenever we had a choice of two or more equally acceptable processing routes, we would choose the one which saved real time at the expense of processing, for the reason that the manufacturer of a fermented whey beverage would have a "crush," not for a short period of time each year as in the grape wine industry, but daily; and to take the advantage of his raw material he must put the beverage to market as quickly as possible.

Now, let me discuss the processing steps which we developed, one at a time, with some of our experiences along the way.

Clarification may be required to provide a whey that is suitable for the UF membrane deproteinization process.

We found that hard cheese wheys often carry significant amounts of whey cream or unseparated milk fat. This can cause fouling of the UF membranes, resulting in less than optimal processing rates and more than normal cleanup. On the other hand, cottage cheese wheys often contain curd fines which may plug thin channel UF systems, resulting in excessive cleaning time and cost.

It is far better to provide a suitable whey by the appropriate use of centrifugal clarifiers or separators common to cheese and dairy operations. The materials removed in this operation are concentrated and are suitable for recycling into allied cheese or dairy products or for routing to animal feeding.

Once suitably clarified, the whey is deproteinized, not by heat or chemical methods which denature the protein, but by ultrafiltration, which preserves the protein in its native form.

We tested heat denaturation and sedimentation as practiced by OSU on the bench scale and found that the heat denatured whey protein settled with difficulty over a long period of time and was not readily removed by pressure filtration, even with large amounts of filter aid.

Conversely, membrane separation was quick and clean, resulting in two useful products, a whey protein concentrate and a sparkling clear permeate for supplementation and fermentation. Further, this route minimized clarification processing downstream of the fermentation.

Ultrafiltration depends upon passing, under pressure, all but protein molecules or fat in the whey through a semi-permeable membrane to yield a water-clear, deproteinized whey permeate as a fermentation base. About 90 percent of the whey volume is passed as permeate when the protein is concentrated to 50 percent on the dry solids basis as the by-product. The whey protein concentrate is suitable for many food applications or for animal

feeding. Several ultrafiltration systems, now commercial in various sizes, are satisfactory for this processing step.

Supplementation of the whey permeate is accomplished simply by adding a small amount of potassium meta-bisulfite as a yeast protector and stimulant and 22 percent of dextrose as a fermentable carbohydrate. Further supplementation is not needed as the whey provides the essential nutrients for yeast growth and fermentation.

Based upon the results of the early study by OSU, we elected to utilize the yeast Saccharomyces cerevisiae sub sp. ellipsoideus, Montrachet strain, as our fermenting organism throughout the study. This yeast, provided to the substrate in commercially available active dry form, fermented the medium to a final alcohol content of 10 percent in seven to ten days at 21°C (70°F) or at ambient temperature.

The alcohol is derived by fermentation of the added dextrose, the lactose present in the whey not being fermented by the selected wine yeast. To ferment the lactose to alcohol would have required a nonwine yeast which would have fermented slowly and provided no more than about 2% alcohol to the beverage. Further supplementation with lactose to increase the alcohol content to 10 percent would have been very costly.

Alternatively, we could have fermented the native lactose and then supplemented with dextrose and the Montrachet yeast. A lactose fermenting yeast currently is not available in a commercial form, as is Montrachet yeast, and would require pure culture microbiology to maintain and bring up inocula for the fermentation. To keep the processing simple and readily manageable, we elected to not ferment the lactose, but keep it intact to provide sweetening and enhance the flavor in the final product.

In the initial stage of fermentation, we provided slow, stirring agitation in stainless steel dairy processing tanks equipped with propellor agitators of the sweep variety. This provided only enough agitation to keep the yeast suspended until active fermentation began. Once actively fermenting, the yeast is kept in suspension by the active bubbling of carbon dioxide generated by the yeast in the process of converting the dextrose to alcohol.

The fermentation proceeds actively for several days, then begins to slow. In general, we found that our ferments were essentially complete by the seventh or eighth day. Fermentation was monitored by measurement of refractometer solids, and two consecutive days readings with no change indicated completion. By that time, bubbling activity had ceased. The ferment was now ready for clarification.

Clarification by centrifugal or filtration methods removes the yeast bio-mass from the ferment and readies it for further processing. We found that the preferred method was centrifugal clarification, to remove the major portion of the cellular material, followed by pressure filtration, with a diatomaceous earth filter aid, to remove the remainder, resulting in a water-clear, fermented beverage base.

We tested clarification of the ferment by sedimentation of the yeast cells in the fermentation followed by decantation. This procedure was costly in time and incomplete in results, whereas the preferred method was quick and positive and resulted not only in a sparkling clear ferment, but highly concentrated forms of yeast and fermentation debris--suitable for animal feeding supplementation or other disposal.

The ferment--or beverage base--at this point in its manufacture is predominantly salty in taste with a definite whey flavor. Attempts to formulate a fruit flavored beverage from this base led to poor results according to informal sensory panels. We resolved that the saltiness and whey flavor must be removed to develop an acceptable beverage.

We evaluated two unit processes known to remove minerals from fluid streams, ion exchange and electrodialysis. Ion exchange is well known in many industries as a demineralizing process; on the other hand, electrodialysis is not, but it is the basis of manufacture of a series of modified whey products widely used in the food, confection, and baking industries and is a technology utilized by the industry represented here today.

Testing both processes, we looked at the advantages and disadvantages of demineralizing before and after fermentation. Ion exchange before fermentation removed the saltiness but depleted the medium of essential nutrients to the point of inhibiting seriously the fermentation, whereas electrodialysis to about 70 percent ash removal reduced the saltiness markedly but did not inhibit fermentation. On the other hand, ion exchange after fermentation removed not only the saltiness, but the unpleasant whey flavors as well; whereas electrodialysis performed less well in removing the whey flavors.

Based on those results, we chose to demineralize after fermentation, using an ion exchange system comprised of a strong acid cation exchanger and a weak base de-acidifier. Although not tested, activated carbon is believed, on the basis of other experience, to be effective in removing the whey flavors if electrodialysis, instead of ion exchange, is utilized as a demineralizing method.

At this point in the process development, the predominant flavor by mouth attribute of the beverage base is alcohol, with slight sweet and acid notes--a good base to accept flavoring.

We surveyed several versions of natural fruit flavors provided by a number of flavor suppliers as compatible with our beverage base. Comparing those flavors in our beverage base to the fruit flavor commercial wines, we selected a black currant flavor extract with other natural flavors for our beverage. Working with the supplier, we required three adjustments to the base flavor system before we were satisfied that our target was met.

Formulation studies with the selected flavor system comprised variations in sweetening, acid, flavor, and carbonation levels.

These studies were monitored by informal panels (project team) and by in-house sensory panels, using preference/acceptance methods. The objective was to adjust our flavor system to match--in acceptance--the target commercial wine. This meant that the sweetness/tartness/alcohol and other flavor traits were in balance.

The formulation developed for acceptance panel testing is characterized as follows:

Demineralized ferment base	75.9	%
Invert syrup	6.26	%
Malic acid	0.236	%
Flavor extract	2.42	%
Water to standardize	15.2	%

This formulation, based on our acid whey fermented beverage base, provided an acceptable approximation to the commercial target wine in terms of the various flavor notes and overall balance of flavor according to small-scale acceptance panels.

Once the wine is satisfactorily fermented and formulated, the next to final processing step is a polishing filtration. This is accomplished with a microporous membrane filter similar to those used for cold sterilization processing. As a processing step, it removes the extremely fine particulates from the wine, which cause haze and sediment, and gives a fine sparkle to the appearance of the beverage. This performed the function which is traditionally accomplished by "racking" grape wines over relatively long periods of time.

Finally, the beverage is chilled, carbonated to two volumes of carbon dioxide, and bottled ready for consumption.

SENSORY EVALUATION

This study was monitored throughout by extensive use of four sensory evaluation techniques:

1. Informal panels.
2. Descriptive flavor analysis (DFA).
3. Discriminatory panels.
4. Small-scale acceptance panels.

The informal panels were used early in the study to screen processing and flavoring systems and select the more feasible alternatives.

Descriptive flavor analysis characterized the aroma and flavor of the commercial wine and of experimental preparations, to help adjust processing and formulation toward the target. With this technique, trained panelists quantify aroma and flavor in terms of key components and develop flavor profiles which describe the product under test. It proved helpful in identifying off-flavor constituents, which could be eliminated by processing in the early part of the study, and in adjusting formulation variables to approximate the profile of the target wine.

Discriminative panels, consisting of Research Center personnel, assisted in adjusting formulation by rating both the experimental products and the target wine in terms of too much or too little of a flavor component.

Acceptance panels were used when other sensory evaluations indicated that we had approached the target wine in terms of critical flavor constituents and balance. Results indicated that in the eyes of the consumer, as well as our in-house panels, we had approximated closely the target wine flavoring balance--although the flavors differed--by advising that the test and target products were equally acceptable.

ECONOMICS

As in any and all studies bearing on a marketable product, the economics of whey beverage fermentation--as well as the product itself--must be satisfactory to give viability to the undertaking.

From data gathered and analyzed in a number of successful pilot runs, we projected the cost of manufacture and bottling in one-fifth gallon wine bottles for small (1,000 gallons per day) and large (100,000 gallons per day) beverage manufacturers. The cost, including capital, labor and materials (with a zero cost for whey), ranged from \$3.47 per gallon to \$2.46 per gallon.

Of those costs, processing accounts for 17 percent, formulating and carbonating for 38 percent, and bottling and capping for 45 percent of the total.

Speaking to reduced sewage treatment costs, the savings for processing 1,000 gallons of whey into beverage amounted to \$113 to \$296--depending on the type of whey. These savings are projected on a sewage treatment cost of \$0.50 per pound of COD.

MARKETING RESEARCH

The proof of the pudding is in the eating, the proof of the beverage is in the drinking; the proof of success is in the eyes, or on the palates, of the consumer.

An independent research group was commissioned to carry out the market research study comparing the finished fermented whey beverage with the target commercial flavored wine. The test was conducted in three geographic locations in the United States: Boston, Chicago, and Los Angeles. At each location, approximately 150 respondents were tested in paired comparison testing of the two beverages. All respondents were qualified on the basis of having personally consumed a pop wine within the preceding month. Persons under legal drinking age or over 35 years of age were disqualified.

To eliminate positional or order bias, the trial order of the two beverages was systematically rotated so that each was tasted first in an equal number of trials; to eliminate brand bias, the samples were presented and tasted without identification.

The conclusions of the study are quoted:

1. In terms of overall preference, whey wine achieved parity with Annie Green Springs (Berry Frost) among black respondents. Among whites, however, there was a definite preference for Annie Green Springs.
2. The flavor strength and tartness of whey wine was, essentially, acceptable. However, whey wine was generally considered to be "too light" in color and too sweet. There was also a slight indication that whey wine was somewhat too carbonated.

SUMMARY

In closing, let me sum up the key points of this study.

Foremost Foods Company Research and Development Center demonstrated a successful transfer of a bench-top process to a pilot or semi-commercial scale, producing a fermented whey beverage with standard dairy/cheese plant equipment. We demonstrated that the process is equally applicable to sweet cheese whey or acid whey.

We developed a flavored variant of this beverage and demonstrated a parity acceptance by a specific segment of the market when challenged by a leading commercial flavored wine. Diagnostics from that test indicate that lack of parity, whenever demonstrated by the fermented whey beverage, was the result of expertise in adjusting the flavor system and was not related to whey as the source of the beverage.

A draft version of the final report is currently in the hands of the Environmental Protection Agency for review. Following that, the final report will be submitted to EPA and will be published in due course under their hand.

AGRICULTURAL RESEARCH TOWARD INCREASED

WHEY UTILIZATION

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The United States Department of Agriculture (USDA) has a long history of research and development activities connected with whey reclamation and utilization. These activities have been sharply increased over the past 10 years when the thrust of global food shortages coupled with strict antipollution regulations forced a reevaluation of previously discarded by-products for food and feed.

The USDA and industrial research efforts have met with some success, as reflected in Table I. These figures, calculated as a percentage of the 1975 production, the first year for which USDA gathered statistics (1, 2), show that the use of condensed and dry whey has been increasing. The slight decline in production of modified whey products such as partially delactosed or partially demineralized whey reflects their decreased use in animal feed in 1976, but this increased again in 1977.

TABLE I.--Production of whey and modified whey products
for food and feed

	1976 Percent of 1975 production	1977
Condensed	166.7	165.5
Dry	111.1	105.0
Modified dry	94.6	104.0
Lactose	76.0	78.3
Whey solids in wet blends	90.7	84.0

Lactose production in 1976-1977 was constant at about 77 percent of the total production for 1975. The baseline 1975 production figure may reflect the effects of high sucrose prices of 1974 because lactose production reached a peak in March of 1975 and declined steadily to half of the March production by the end of the year (1). Monthly lactose production figures for 1976 and 1977 were constant.

The USDA and state agencies still have an active research program pertaining to whey utilization. Of 83 projects that were initiated in January 1974 or later, Agricultural Research is responsible for 19, the Cooperative States Research Service for 45, and the State Agricultural Experiment Stations for 19. There are also 39 projects relating to lactose; however, this figure is high because some of the projects listed for whey were cross-indexed under lactose.

Whey research projects currently underway at the Eastern Regional Research Center (ERRC) in the Dairy and Engineering and Development Laboratories are as follows:

1. Derivatization of lactobionic acid.
2. Oxidation of lactose to acidic disaccharide derivatives.
3. Innovative whey processing and use.
4. Whey based cultured products.
5. Prevention of flavor deterioration in stored whey protein concentrates.
6. Factors affecting the film properties of whey foams.
7. Whey components as humectants for intermediate moisture foods.
8. Nutritious beverage powders formulated from whey solids and vegetable proteins and/or fats.

This research is conducted with 16SY and some support help. The present paper reports progress made under these work units.

LACTOSE UTILIZATION RESEARCH

The extensive lactose utilization research program at ERRC was discussed in detail at the 1976 Whey Products Conference (3), with special emphasis on lactose derivatives. However, increasing the utilization of lactose still remains a major unsolved problem in the dairy industry.

Many sugar acids can form water soluble metal complexes because of the ability of the carboxyl and hydroxyl groups to bind cations in ring form by means of coordinate and covalent bonds (4). A knowledge of the specific conditions under which such complexing is most effective could lead to new outlets for these products (5).

An example of such a sugar acid is lactobionic acid, which may be prepared readily from lactose under mild oxidizing conditions (6). This product can be used in alkaline solution as a chelating agent for heavy metals, such as iron, under conditions where EDTA is not effective. However, gluconic acid, a sequestrant familiar to the soft drink industry among others, is about twice as effective as lactobionic acid for this purpose (7).

Calcium, cupric and ferric salts of lactobionic acid have been prepared (8). These lactobionates may have potential as a means of supplying heavy metals to plants; evaluations are still underway.

To date, it has been found that esters formed from lactobionic acid are not stable. However, lactobionic acid may be cyclized by dehydration to form a lactone (9); as a result, a reactive chemical has been derived from lactose. For example, the lactone is reactive with amines to form stable amides (10). An extensive examination of the characteristics of nitrogenous derivatives such as N-dodecyl-lactobionamide or 1,6 dilactobionamido hexane is presently underway (8). No antimicrobial activity (11) or other special use for any of these derivatives has been identified as yet.

α -Lactose may be isomerized to lactulose in which the glucose moiety of lactose has been converted to fructose (12). It was thought that lactulose might possess sweetness, humectant, and solubility properties which would make it useful in food applications (13).

For testing, lactulose was prepared as follows (14):

1. Stir lactose in saturated $\text{Ca}(\text{OH})_2$ solution 48 hours at room temperature.
2. Remove residual lactose by concentration, crystallization.
3. Remove residual calcium ion by IR 120 ion-exchange resin.
4. Remove glucose, galactose, and color with charcoal.

Following this procedure, lactulose may be recovered in 15 percent yield as a 70 percent syrup. This syrup has shown no tendency to crystallize or develop color even after 3 years of storage at 4 C.

Extensive organoleptic evaluations were conducted to gain some knowledge of the sweetness of lactulose when compared to sucrose. The curve in Figure 1 describes the sweetness of lactulose, equilibrated for 16 hours before being tasted, over the range of concentration 5-35 percent (W/V) relative to sucrose. This means, for example, that a 10 percent solution of lactulose has sweetness equal to about a 5 percent sucrose solution. Although not shown, a solution concentration of 13.5 percent lactose would be necessary for equal sweetness (15).

Lactulose also has potential as a humectant. Data indicate that lactulose is more effective than sucrose in controlling water activity. To obtain an a_w of 0.85, only 47.4 percent lactulose solution (52.6 percent water) is required compared to a 67.3 percent sucrose solution (32.7 percent water). To obtain an a_w of 0.90, 30 percent lactulose solution (69.3 percent water) is required compared to a 58 percent sucrose solution (41.5 percent water). This effect was apparent at all concentrations examined (13).

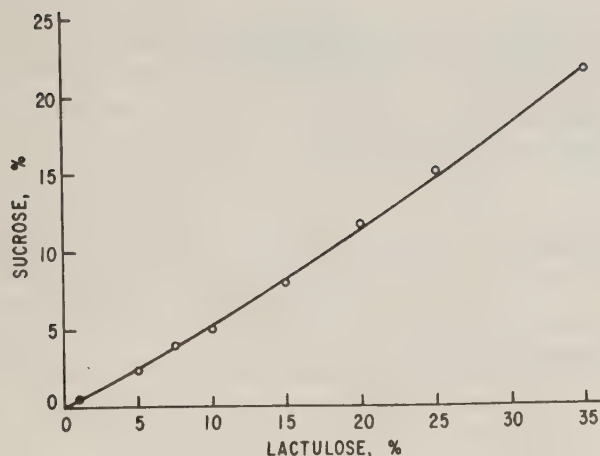


Figure 1.--Plot of lactulose concentration versus sucrose concentration for equal sweetness.

Some bread baking studies have been carried out with lactulose. Straight dough breads made with lactose or lactulose in a reduced sucrose and shortening formulation produced more tender breads as measured by compression; volume and taste panel scores were no different than controls, however. Sponge and dough breads containing lactulose or lactose were equivalent to controls in all respects (16).

HYDROLYZED LACTOSE STUDIES

Some potential uses for whey which had been treated with lactase enzyme (β -galactosidase) to hydrolyze lactose to glucose and galactose were described at the 1974 Whey Products Conference (17). Some advantages of lactase treatment for product applications include reduced lactose content, prevention of lactose crystallization, increased solubility, increased sweetness, and more rapidly fermentable sugars.

Clear, nearly colorless syrups may be prepared from lactose either by enzymatic treatment or by an older method, hydrolysis with hydrochloric acid and heat. A flow sheet describing the preparation of enzyme processed syrups is shown in Figure 2.

A suspension of either 0.1 percent purified lactase (W/V) or 0.2 percent crude lactase was added to 3 liters of 0.584 M lactose dissolved in distilled water and brought to pH 6.4 with 0.01 M phosphate buffer. After 6 hours at 30 C, the enzyme was inactivated by heating to 75 C; hydrolysis was over 90 percent. The solution was decolorized with 1 percent charcoal, after which the filtrate was demineralized by being passed over Dowex 50W-X8 in the H⁺ form. Filtrates at pH 2.2 were then passed over Dowex 2-X8 in the OH⁻ form, after which the eluates were adjusted to pH 5.4 - 5.6, then condensed in vacuo to 60-66 percent total solids (TS) at 60-70 C (18).

0.58 M lactose, pH 6.4

↓
Saccharomyces lactis lactase
Hold 6 hours, 30 C
Heat to 75 C
1 percent charcoal
↓ Filter

Filtrate

↓
Cationic resin
Anionic resin

Eluate

↓ Condense to 60 percent total solids
Syrup pH 5.6 and 5.4

Figure 2.--Flow sheet for the preparation of syrups by enzymatic hydrolysis of lactose.

The hydrolyzed lactose syrups were as sweet as sucrose syrups above 50 percent TS but less sweet at lower levels (Figure 3). Although increasing lactose hydrolysis from 75 to 95 percent increased sweetness, observed differences were very small.

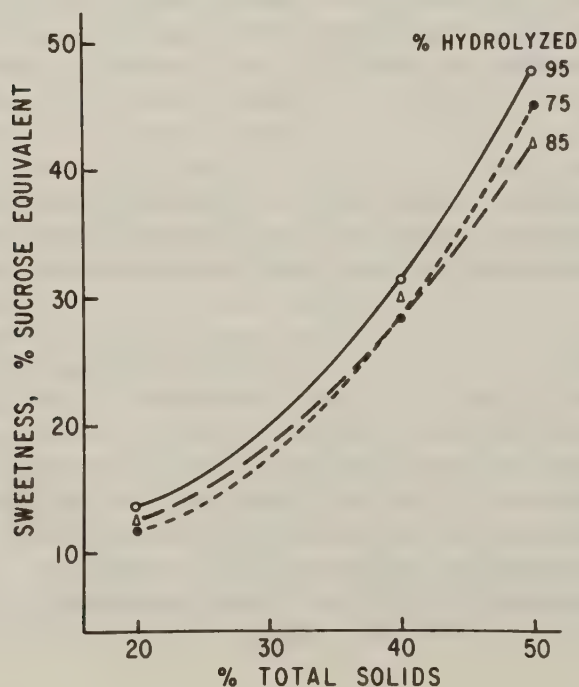


Figure 3.--Effect of extent of hydrolysis of lactose in syrups on their sweetness relative to sucrose.

The degree of hydrolysis affected the crystallization rate. Crystallization occurred more rapidly in syrups with 95 percent hydrolyzed lactose irrespective of the TS content (Table II). Analysis of the crystals formed in the 95 percent hydrolyzed syrups showed them to be primarily galactose; this could be expected because the solubility limit of galactose is 32.1 percent, whereas that of glucose is 50.8 percent (19). Syrups of 60 percent TS, low enough to resist crystallization, formed mold in less than a month.

Crystallization could be retarded by pasteurizing the syrup and sealing the container (Table III); this also prevented microbiological deterioration. Best stability was observed in pasteurized syrups with 75 percent hydrolyzed lactose and 63-66 percent TS (18).

TABLE II.--Crystallization rates of unheated syrups made from lactose

Percent enzymatic hydrolysis	Days to crystallization at 23 C (Total solids, percent)		
	60 percent	63 percent	66 percent
95	7	2	2
85	>40 ¹	16	4
75	>50 ¹	>250	>250

¹Mold formed in 28 days.

TABLE III.--Crystallization rates of enzyme processed syrups containing 60 percent total solids

Percent hydrolysis	Weeks to crystallize at 23 C	
	Unheated	Heated to 75 C and sealed
95	<1	6-12
92	1	15>47

Because of their sweetness at high solids levels and humectant properties, these syrups could find application in confections. To test humectant properties, milk caramels were selected as the test candy (20) and formulated as in Table IV. Syrups prepared from both hydrolyzed lactose and lactase treated sweet whey with 90 percent of its lactose hydrolyzed were tested. When whey was used as the humectant, the amount of sweetened condensed whole milk in the formulation was reduced because of the protein in the whey.

Butterfat and sucrose were added to levels present in the other two formulations. Both humectants were added at the 5 percent level. All caramels with added humectant showed less crystallization at the surfaces of the rolled layers and less shrinkage during storage at 23 C and 40 percent relative humidity for 2½ months than did the control.

Evaluations of the caramels prepared with 5 percent humectant are listed in Table V. After 6 months storage, the control showed a significantly greater moisture loss than either of the caramels containing added humectant. Samples containing the hydrolyzed lactose syrups showed highest flavor score on a 9 point hedonic scale (21). Although there was no difference in liking for the three caramels in the first test, the second test showed that both the control and the product containing lactase-treated whey were significantly less well-liked. The sample containing lactase-treated whey also showed a significantly greater hot spread than the other two samples. There was little difference in initial moisture, however.

TABLE IV.--Caramel formulations

Ingredient	Control	Hydrolyzed lactose syrup	Hydrolyzed lactose sweet whey
Sweetened condensed whole milk	1000	1000	825
42DE corn syrup	600	600	600
Sucrose	200	200	273
Hard fat (Paramount C)	100	100	100
Syrup or whey	-	130	160
Butterfat	-	-	16
Salt	4	4	4
Lecithin	3	3	3
Vanilla extract	8	8	8

The availability of hydrolyzed lactose whey as a spin-off of the ERRC cheese research program prompted an evaluation of this by-product as an ingredient in ice cream, since ice cream and other frozen desserts represent a logical outlet for whey (22). Formulations evaluated are listed in Table VI. Two levels of lactose hydrolysis were examined. With increasing levels of whey solids, both the milk solids not fat and the sucrose level could be

reduced in the formulation. This reduction resulted in a decrease in protein with increasing whey solids, amounting to a 20 percent decrease in the formulation containing 11 percent whey solids and a 30 percent increase in ash content. This work was undertaken prior to the dropping of the proposed ice cream standards; the only formulation listed in Table VI which would meet present standards is that containing 2.75 percent whey solids.

TABLE V.--Evaluation of caramels made with 5 percent humectant

Evaluation	Control	Hydrolyzed syrup	Hydrolyzed sweet whey
Caramel moisture, percent	9.22	9.07	8.89
Hot spread, cm ² /g	1.08 ²	1.02 ²	1.41 ¹
Taste hedonic panel score ⁴	7.21 ¹ 7.12 ^{2, 3}	7.75 ¹ 7.93 ¹	7.21 ¹ 6.43 ³
Percent moisture loss ⁴ 6 months, 23 C, 40 percent RH	1.40 ¹	1.02 ²	0.57 ³

⁴Common numbers - not significantly different across at the 5 percent confidence level.

TABLE VI.--Ice cream formulation¹

Percent whey solids ²	Percent	
	Milk solids not fat	Sucrose
0.00	11.0	15.00
2.75	9.5	13.75
5.50	8.0	12.50
8.25	6.5	11.25
11.00	5.0	10.00

¹12 percent fat and 0.14 percent stabilizer.

²67 percent or 79 percent hydrolyzed lactose.

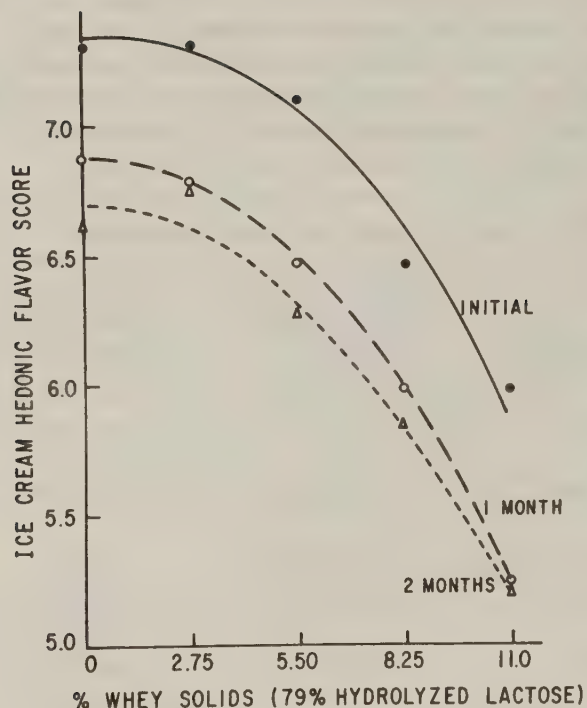


Figure 4.--Effect of concentration of whey solids on the hedonic flavor score of ice cream.

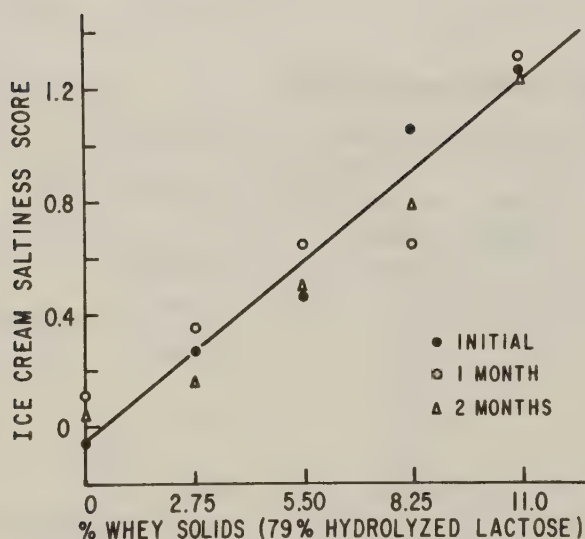


Figure 5.--Effect of concentration of whey solids on saltiness score of ice cream.

The hedonic flavor scores (21) given the ice creams decreased with increasing levels of whey solids (Figure 4). There was also a reduction in flavor score between the initial tasting and the tasting after one month of storage; all scores were above 5, however, representing some liking for the product, even at highest whey levels.

The decline in flavor score with increasing whey solids could be attributed to excess saltiness, as shown in Figure 5. Judges were asked specifically to score the ice creams for saltiness. Saltiness score increased with increasing levels of whey solids and became significantly different from the control in the samples containing 5.5 percent whey solids or more.

DEMINERALIZATION

Saltiness of wheys in general has frequently been a barrier to whey utilization, especially in the case of whey permeates, the by-products of ultrafiltration operations. With the appearance on the market of ion exchange resins thermally regenerable with hot water instead of with acids and bases, thereby reducing operating costs (23), their potential for demineralization of whey permeates was immediately apparent.

The effects of demineralization of the ultrafiltrate on the yield of lactose by crystallization were evaluated according to the treatment scheme in Table VII (24). The ultrafiltrate is first passed over a Duolite column to obviate possible irreversible fouling of the Sirotherm resins by residual protein. Riboflavin was also presumed to be removed in this step, since the permeate was completely decolorized. Because Sirotherm resins have been used mainly to treat brackish water (25) and, in water treatment, the most economical procedure was to remove the divalent cations and monovalent cations in successive steps, this sequence was followed for treatment of the permeate. At the end of the treatment sequence, 76 percent of the calcium, 90 percent of the magnesium, and virtually all of the sodium and potassium ions were removed. Calcium and magnesium were removed because preliminary experiments with simulated ultrafiltrate showed that these cations reduced lactose yield by about 14 percent.

The yield of α -lactose monohydrate, crystallized from a 50 percent total solids solution, was significantly greater from the completely deionized solution than from ultrafiltrate from which only divalent cations had been removed or from ultrafiltrate that had not been passed over the Sirotherm resins (Table VIII). Lactose crystallized from solutions from which calcium and magnesium or all four cations had been removed met all the criteria for edible lactose (26). Explanations for the differences in yields must await more detailed studies of the numerous factors involved in lactose crystallization.

FLAVOR

Whey is an excellent source of vitamin B₂, riboflavin, containing from 2 to 2.2 mg per 100 g of solids (27). Riboflavin is implicated in the development of light-induced off-flavors in milk and dairy products (28). Lumichrome, the structure of which is shown in Figure 6, along with the mass spectrum, has been clearly established to be a major photodegradation product of riboflavin in milk exposed to sunlight; a method has been developed for its isolation (29). Traces of this compound may be detected just prior to the onset of off-flavor; whole milk has a strong off-flavor when only about

1 percent of the riboflavin has degraded. Lumichrome also forms and can be detected after only 1 hour of exposure to fluorescent light. Lumichrome has been found in commercially spray dried whey protein concentrates. This isolation method may offer an objective means of identifying samples that have undergone photochemical reactions as the result of excessive exposure to light and may be off-flavored as a result.

TABLE VII.--Treatment scheme for the demineralization of cheddar whey ultrafiltrate

Resin ¹	Purpose
Duolite S-761	Removes protein
Sirotherm TR-10 ($\bar{X}_o = 0.5$)	Removes Ca^{++} , Mg^{++}
Duolite C-20 (Na)	Softening step
Sirotherm TR-10 ($\bar{X}_o = 0.1$)}	Removes monovalent ions (Na^+ , K^+)
}	
Sirotherm TR-20 ($\bar{X}_o = 0.1$)}	

¹Reference to brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

TABLE VIII.--Yields of α -lactose monohydrate from treated ultrafiltrate and a control

Source of lactose	Percent yield
α -Lactose monohydrate control	67.2 ± 0.5
Duolite S-761 treated ultrafiltrate	43.5 ± 1.8
Ca^{++} & Mg^{++} -free ultrafiltrate	39.6 ± 0.7
Deionized ultrafiltrate	56.4 ± 0.8

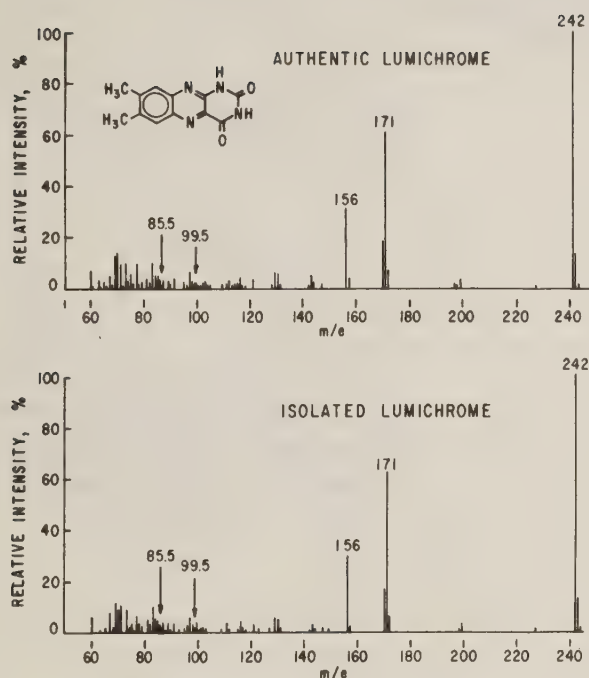


Figure 6.--Comparison of mass spectra of lumichrome isolated from skim milk exposed to sunlight and the authentic compound.

WHEY FERMENTATION

A major problem in using whey as a fermentation substrate to date has been that relatively few organisms can ferment lactose, Kluyveromyces fragilis being the most efficient (30). In a commercial application for whey wine production, dextrose was added to the fermentation medium so that a typical wine yeast, Saccharomyces cerevisiae could be used (31). This means that the lactose was left intact.

The availability of lactase-treated acid whey at ERRC led to an investigation of alcohol production by S. cerevisiae and K. fragilis (30). Complete fermentation of the sugar and maximum alcohol production by K. fragilis required 120 hours at 30 C in lactase-treated acid whey compared to 72 hours in the control (Figure 7). This was due to a diauxic fermentation pattern in the lactase-treated whey, with glucose being fermented before galactose. S. cerevisiae produced alcohol from glucose more rapidly than did K. fragilis but fermented galactose only when pregrown on galactose.

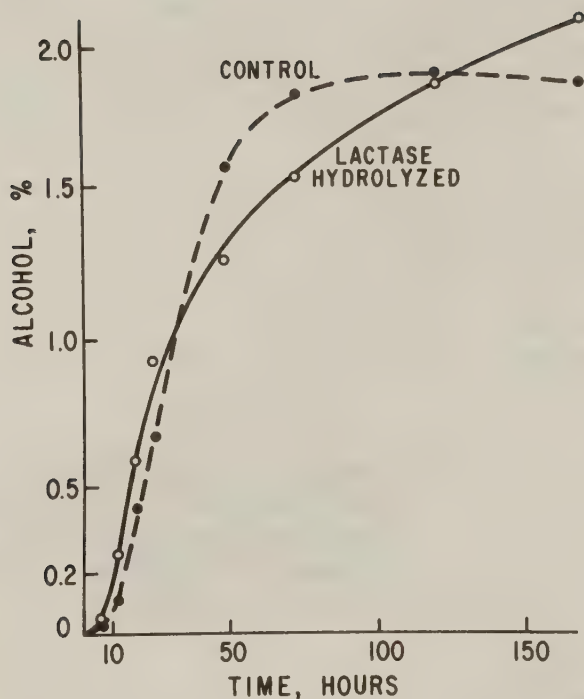


Figure 7.--Alcohol production by glucose-pregrown *Kluyveromyces fragilis* in control and lactase hydrolyzed acid wheys.

A whey permeate is better than acid whey as a starting material because the presence of protein generally causes problems with clarity in the manufacture of any alcoholic beverage (32). Alcohol production from acid whey permeates with *K. fragilis* and *S. cerevisiae* is shown in Figure 8 (33). With *S. cerevisiae*, alcohol yields of 6.5 percent were obtained in lactase-treated permeates condensed to 30-35 percent total solids prior to inoculation. The maximum yield obtained with *K. fragilis* was 4.5 percent at 20 percent total solids in the lactase-treated permeate and 3.7 percent at 10 percent total solids in the control permeate. Although *S. cerevisiae* efficiently converted the glucose present to alcohol, galactose, comprising about half of the available carbohydrate, was not utilized at all. This means that, even though the alcohol yield was higher, the process was wasteful in that a good proportion of substrate was not utilized. It was concluded that, although lactose prehydrolysis was advantageous in that microbial species unable to ferment lactose could be utilized, a commercially feasible process must consider diauxic problems and have an efficient means of rapidly converting galactose to alcohol.

With increasing use of polysaccharide gums as stabilizers in engineered foods, the possibilities of gum synthesis in whey based media have been examined at ERRC (34). Experiments were conducted with *Xanthomonas campestris* to study the carbohydrate utilization patterns in different whey types and the amounts of gum produced. β -Galactosidase (lactase), assayed in cells grown in different media, proved to be part of the constitutive system, since the enzyme was produced in low levels in glucose media.

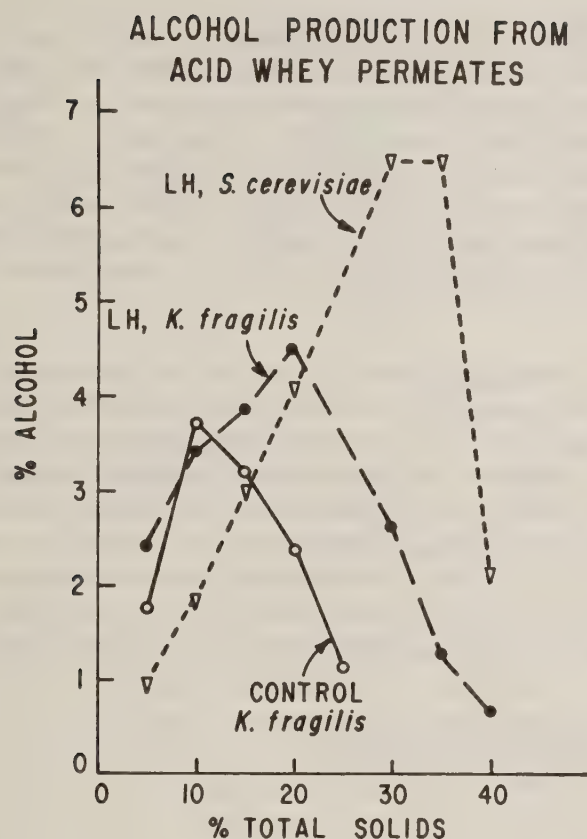


Figure 8.--Alcohol yields obtained by fermentation of lactase hydrolyzed whey permeate and whey permeate by Saccharomyces cerevisiae and Kluyveromyces fragilis.

It was necessary to induce and stabilize mutant strains to convert lactose to microbial polysaccharides; of 32 mutant strains cultured, only 8 survived after two subculturings. They could be maintained on lactose agar media but grew poorly in whey permeate.

Gums could be produced in lactase-treated acid whey permeate. Good gum production was obtained when the permeate was diluted to 5 percent total sugar calculated as glucose or diluted further to a minimum of 2.5 percent total sugar and adjusted to pH 7.0 with potassium hydroxide. This process was carried out under slightly alkaline conditions; the carbohydrate substrate was 96 percent metabolized and 55 percent was converted to gum. Evidence also showed that glucose and galactose were utilized simultaneously. Highest viscosity levels were observed 8-10 days after inoculation. The available carbohydrate was 50 percent depleted in 4 days; about 50 percent of the available protein and lactate had disappeared after 3 days. The gum was isolated and purified by solvent and salt fractionation; the pyruvate content proved to be 3.2 percent. These gums are undergoing further tests at the present time.

HIGH PROTEIN BEVERAGES CONTAINING WHEY

Since 1973, considerable time has been spent on research and development activities related to the production and properties of whey soy drink mix, a nutritious beverage powder specifically designed as a dietary supplement for preschool children receiving inadequate protein (35). To date, the U.S. Department of Agriculture has purchased over 10 million kilograms of whey soy drink mix since distribution first began in 1974 (36). This year, it is planned to ship about 3 million kilograms for use in child feeding programs in Pakistan, Bolivia, Chile, and Haiti, even though there is a worldwide surplus of nonfat dry milk.

Peanut based products often have been proposed and used in overseas programs because peanuts are a surplus commodity in the United States; in addition they are a familiar crop in many of the developing countries where Food-for-Peace programs operate (37). Based on experience gained in the work with whey soy drink mix, a whey peanut blend has been prepared as in the formulation in Table IX (38). The product, containing 50 percent sweet whey solids, is intended for beverage use after reconstitution with water. The reconstituted whey peanut blend has a more acceptable flavor than whey soy drink mix has; its hedonic rating was 6.1, significantly higher than the 4.9 received by whey soy drink mix.

TABLE IX.--Formulation of whey
peanut blend

Ingredient	Percent
Sweet whey solids	50.0
Defatted peanut flour	24.6
Soybean oil	20.0
Corn syrup solids	5.4

Unfortunately, this product in its present stage of development lacks the storage stability of whey soy drink mix. Peroxides develop rapidly in the whey peanut blend during storage (Table X); even at a moderate storage temperature, this development could be correlated with detection of oxidized flavor by trained judges after only 53 days of storage. Such a serious storage stability problem renders this product unacceptable for use in food donation programs at present, even though with a PER of 2.0, it has the nutritional quality required. This problem is still being investigated.

TABLE X.--Peroxide values (meq O₂/kg fat) of whey peanut blend stored for varying lengths of time

	Initial	Storage time - days					
		25	53	81	109	137	165
Control N ₂ pack, stored -18 C	10.1	9.3	8.4	8.3	11.3	14.2	15.2
Air pack, stored 20 C	-	17.7	27.7	30.9	37.1	45.9	55.4
Air pack, stored 37 C	-	19.4	32.0	38.0	57.4	74.6	82.1

WHEY PROTEIN CONCENTRATES

The ERRC whey research effort also has been expended on the question of why an aqueous dispersion of a whey protein concentrate (WPC), when whipped to a foam, collapses when heat is applied. A 20 percent total solids dispersion of WPC carries the sucrose and flour very well when whipped into an angel food cake batter; when placed in the oven, the batter rises until, after about 12-15 minutes of baking, total collapse occurs (39).

Physical properties of the angel food batters are listed in Table XI. A 14 percent WPC batter is shown for comparison because the TS of liquid egg white amounted to 14 percent; in practice, a 20 percent WPC batter was used. The viscosities were quite different; however, with increased viscosity, foam stability should increase. Foam densities and surface tension of the 20 percent WPC batter and the egg white batter proved to be close.

TABLE XI.--Physical properties of aqueous dispersions of whey protein concentrate compared to egg white at pH 4.7 with 44 percent sucrose added

Sample	Liquid density g/cc	Foam density g/cc	Apparent viscosity cp	Surface tension dynes/cm
WPC (14 percent TS)	1.229	0.19	34.2	48.6
WPC (20 percent TS)	1.242	0.27	79.3	49.1
Egg white (14 percent TS)	1.226	0.24	25.3	52.6

TABLE XII.--Effect of whipping for 10 minutes
on solubility of 1.5 percent protein solutions
in 0.1 percent sodium chloride at pH 4.7

Protein	Percent insoluble after whipping
β -Lactoglobulin	5.7
α -Lactalbumin	2.3
Bovine serum albumin	0
Mixed whey proteins	0
Ovalbumin	3.7
Egg white	11.1

Egg white is believed to form a stable foam because of the tendency of ovalbumin, the major egg protein, to undergo a configurational change at an air-water interface, resulting in solubility loss (40, 41). The tendency of solutions of the whey proteins to insolubilize when whipped was examined (Table XII). No insolubilization of bovine serum albumin or of the mixed whey protein dispersion occurred. β -Lactoglobulin, the principal whey protein, was more sensitive to surface denaturation than ovalbumin was under these conditions. The mixed whey proteins must either contain factors or exist in a conformation which stabilizes the system against surface denaturation.

Prolonged whipping leads to the formation of smaller bubbles; the resultant increase in surface area means that there are more air-water interfaces available from which liquid can drain, until at some time the bubble becomes so weak that it collapses.

Bubble thinning and bubble collapse must be related in some way to the film forming properties of the proteins. Knowledge of the conformation of a protein at the air-water interface may be gained by examining the conformation of the protein when it has been spread in a thin film on the surface of a solvent and then compressed. A method has been devised whereby the film is spread by a Langmuir film balance, picked up at the desired compression on a quartz surface and examined for conformation by circular dichroism spectroscopy and UV spectroscopy (42). The curves in Figure 9 are those of polymethylglutamate and polyalanine which were used as model proteins in the film balance. The plateaus on two of the curves represent the points where the protein is no longer a monolayer. Analysis by circular dichroism showed the two s-shaped curves to be α -helices; the smooth curve is that of polymethylglutamate in the β -conformation.

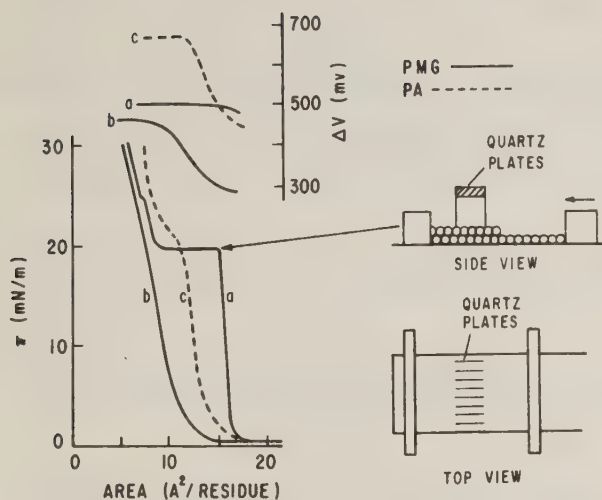


Figure 9.--Pressure (π) - area and surface potential (DV) isotherms of polypeptide monolayers. Polymethylglutamate spread from (a) chloroform-dichloroacetic acid (99:1 vol); (b) pyridine-chloroform (98:2); (c) polyalanine spread from chloroform-dichloroacetic acid (99:1).

Because this method is still being developed, no data for the whey proteins are yet available. However, increased knowledge of the film forming properties of the whey proteins should shed some light on their behavior as a foam.

CONCLUSION

From the progress reported here, it is evident that the potential for using whey in its various forms remains strong. Many products now available commercially contain large quantities of whey, benefiting both the processor and the consumer. The greatest challenge for the future lies in exploring those options for whey utilization that do not compete directly with skim milk powder. ERRC research scientists are interested in nutrition, nutrient stability and food safety and quality research programs, and they remain available for consultation concerning industrial problems.

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INTRODUCTION

The dairying industry, worldwide, has long manufactured products like cheese and casein, which are based on the coagulation of the main protein component in milk-casein. These products incorporate upwards of half of the solids in milk or skim milk. The remaining solids, together with much of the water, are present in the whey. The total world production of fluid whey for 1977 is estimated to exceed 51.6 million tonnes (tons). This represents some 3.1 million tonnes of whey solids consisting of about 500,000 tonnes of whey proteins and 2.6 million tonnes of lactose, together with additional amounts of mineral salts and water-soluble vitamins.

The low solids content of liquid whey and its highly perishable nature traditionally have made its processing difficult and, in many areas, the economics doubtful. As a consequence, whey has long been regarded as a waste by-product to be disposed of by any means deemed 'convenient.' At the beginning of the 1970's, with the consolidation of many small dairy factories, whey production became centralized, and the problems of disposal and/or utilization of whey were magnified. Concurrently, there was a growing awareness of the importance of protecting the environment and of avoiding pollution. The dairying industries of the world, therefore, were faced with decisions as to whether to attempt to utilize the milk solids lost in whey or to pay the cost of disposal.

The economics of whey utilization and disposal are obviously complex, especially in the light of local regulations, practices, and the competition from other 'milk' powders. Therefore, unqualified predictions or projections on the future employment of whey would be largely unproductive. In my view, what may be more appropriate is to consider whey production and utilization patterns in various countries over the past five years and, based on an analysis of these trends, to make some qualified predictions and projections. In no way is this contribution intended to constitute an exhaustive account of how whey is processed worldwide. Neither my competence nor the time at my disposal would permit this. What follows is a brief account of whey production and utilization patterns in different parts of the world.

USA

The greatest individual concentration of fluid whey production is in the U.S. (Table I). The figure for total fluid whey production in 1977 is estimated at about 18 million tonnes. This represents a 25% increase over the 1975 figure of 13.4 million tonnes. The breakdown of the 1977 production figures are as follows--15.6 million tonnes of sweet whey (990,000 tonnes of whey solids), or about 87% of the total, and some 2.4 million tonnes, or 13% of total, as acid type whey (equivalent to 140,000 tonnes of whey solids).

TABLE I.--Total production of fluid
whey in USA

	TONNES x 10 ⁶
1975	13.4
1976	16.7
1977	18.2

Estimated from USDA statistics

This increase in whey production has naturally paralleled the increase in cheese production. Cheese constitutes by far the largest end use of milk for manufacturing. In 1977, nearly 24% of the total milk produced was utilized for cheese making. Per capita consumption of cheese in the U.S. has soared in the ten year period 1966-1976. In 1977 it stood at about 7 kg per person per annum. This growth and the demand for cheese has resulted from changes in eating habits, rising consumer income, and changing life styles. The increase in the demand for cheese is likely to continue, although probably not at the same accelerated rate. Projected decreases in beef supplies in 1979 will tend to push beef prices upwards. Increases in beef prices are accompanied by increased demand for other meat and dairy products. Demand for cheese increased in the past whenever beef prices rose. Increases in the total amount of fluid whey produced, therefore, may be expected.

Best estimates indicate that for 1977 (the last year for which data are available) some 53.2% of the total whey solids produced were further processed in one form or another. In 1973, the percentage of fluid whey produced which was further processed was 56.2%. These percentage figures can, however, be somewhat misleading. Although the percentage processed figure decreased, the total whey solids processed increased from ca. 510,000 tonnes in 1975 to ca. 540,000 tonnes in 1977. Table II contains data on the production of dried whey. A decrease in the total tonnage produced occurred in 1977 compared to 1976, but an increase in the production of concentrated whey solids occurred in the same period (Table III). This latter route obviously represents a saving in processing costs. Table IV contains comparative data on the end use of whey in animal feeds for the years 1976 and 1977. An increase in the total tonnage of sweet whey solids and a decrease in the tonnage of acid whey solids incorporated into animal feed occurred during this period. Little overall change in the total amount of dried whey used in human foods occurred in 1977 (Table V). There were changes in the detailed disposition of dried whey over the various product categories.

Comparative data on the end uses of modified whey in human foods are given in Table VI. Modified whey includes partially delactosed, partially

TABLE II.--Production of dried
whey in USA

	Tonnes	
	1976	1977
Human Food	240,060	234,740
Animal Food	90,820	80,580
Total	330,880	315,320

Estimated from USDA/WPI statistics

TABLE III.--Production of concentrated
whey (solids basis) in USA

	Tonnes	
	1976	1977
Sweet Whey		
Human Food	53,850	58,210
Animal Feed	11,910	27,096
Acid Whey		
Human/Animal	5,570	6,300
Total	71,330	91,606

Estimated from WPI statistics

TABLE IV.--Comparison of end uses of whey & whey products
in animal feed (USA)--tonnes

	1976		1977	
	Sweet	Acid	Sweet	Acid
Dairy/Calf/Cattle	89,500	21,000	88,250	18,000
Poultry	4,000	3,500	3,200	2,600
Pig	25,000	38,000	30,100	32,500
Pet	13,500	300	12,500	250
Others	11,500	4,500	11,500	7,650
Total	143,500	67,300	145,550	61,000

Source: Estimated from WPI and USDA statistics

TABLE V.--Comparison of end uses of dried whey
in human food (USA)--tonnes

	1976		1977	
	Sweet	Acid	Sweet	Acid
Bakeries	46,500	500	48,500	300
Blends	20,000	500	27,500	150
Dairies	70,000	50	72,500	1,000
Meat Proc.	1,000	---	350	50
Candy	5,000	---	7,700	---
Soft Drink	300	---	200	---
Dry Mix	10,000	---	12,500	---
Soups	350	---	350	---
Margarine	150	---	350	---
Chemicals	100	---	150	---
Others	35,000	---	19,200	---
Total	188,400	1,050	189,300	1,500

Source: Estimated from WPI statistics

TABLE VI.--Comparison of end uses of modified whey
in human food (USA)--tonnes

	1976		1977	
	Sweet	Acid	Sweet	Acid
Bakery	2,500	900	3,800	---
Dairy	6,800	---	5,900	---
Candy	1,150	---	1,000	---
Soup	50	---	---	---
Infant Food	5,150	---	5,200	---
Dry Mix	200	---	150	---
Other	<u>3,100</u>	<u>1,000</u>	<u>2,300</u>	<u>---</u>
Total	18,950	1,900	18,350	---

Source: Estimated from WPI and USDA statistics

demineralized and partially delactosed and demineralized solids. These products result from processes such as electrodialysis, ultrafiltration, and ion-exchange. The 18,350 tonnes of modified whey solids incorporated into human foods in 1977 represent less than 5% of the total whey solids further processed in that year. An additional 70,000 tonnes of modified whey solids were manufactured and incorporated in animal feeds. The estimated total capacity for the production of modified whey solids in the U.S. exceeds 5 million tonnes of fluid whey per annum. In 1977, modified whey solids were produced at about one-third of the total capacity. This should change markedly with changes in the standards of identity permitting wider use of modified whey solids in foods. Some 45,600 tonnes of lactose were produced in the U.S. in 1977 (Table VII). The increase in lactose production has occurred over the past two years. This trend is expected to continue.

CANADA

Data on Canadian production of fluid whey for the years 1975 to 1977 are given in Table VIII. An increase of some 11% in the total volume of whey produced occurred during this period. It is estimated that approximately 52.6% of the total whey produced in Canada was utilized in 1977. The percentage of whey utilized in 1975 was ca. 33.1%. The major part of the whey solids goes for the manufacture of whey powder for human and animal outlets (Table IX). Production of whey powder has more than doubled in the five year period from 1973 to 1977 (Table X). This trend is likely to continue for the next three years. Use of whey solids for the manufacture of lactose is expected to increase to some 6,200 tonnes by 1980 (this would represent an increase of 50% over the 1977 figures).

TABLE VII.--Comparison of end use of lactose
in human food (USA)--tonnes

	1976	1977
Pharmaceutical	6,700	7,150
Infant Foods	17,400	17,300
Fruits and Vegetables	---	150
Diet Food	7,300	8,500
Dairy Products	5,400	3,300
Fruit jellies, Preserves	---	---
Others	<u>5,400</u>	<u>9,200</u>
Total	42,200	45,600

Source: Estimated from WPI and USDA statistics

TABLE VIII.--Total production of
fluid whey in Canada

	Tonnes x 10 ⁶
1975	1.35
1976	1.40
1977	1.50

Source: Department of
Agriculture Canada

TABLE IX.--Utilization of whey solids in Canada

	1977
	1,000 Tonnes
Whey Powder	45.4
Condensed Whey	1.7
Evaporated Whey	6.8
Whey Cheese	0.9
Lactose	4.1

Source: Department of Agriculture
Canada

TABLE X.--Production of
whey powder in Canada

	1,000 tonnes
1973	21.9
1974	31.9
1975	35.0
1976	41.1
1977	45.4

Source: Department of Agriculture
Canada

One very acute problem associated with whey processing in Canada is the large number of small factories producing cheese. In 1977 there were 130 individual cheese factories. Of these, 75 individual factories produce less than 3,000 tonnes of fluid whey per annum. Overall, some 90 factories collectively produce approximately 7.5% of the total whey. One possibility for increased utilization of whey in Canada is the direct use of fluid whey for pig feeding. This approach is actively researched and promoted by the Canadian Department of Agriculture. A conservative estimate indicates that, if implemented, this course of action would provide utility for an additional 15,000 tonnes of whey solids per annum. As a consequence, the percentage of total whey utilized would increase to ca. 78%.

AUSTRALIA

Table XI contains data on the production of fluid whey in Australia for the period 1974/75 to 1977/78. Current production of fluid whey is ca. 1.47 million tonnes. Of this, 850,000 tonnes results from the manufacture of cheese and 330,000 tonnes from the manufacture of casein. Patterns for the production of cheese and casein over recent years are given in Table XII.

TABLE XI.--Production of fluid whey in Australia

	Tonnes x 10 ⁶
1974/75	1.24
1975/76	1.52
1976/77	1.36
1977/78*	1.47

*Preliminary

Source: Estimated from Australian Dairy Board Statistics

TABLE XII.--Australian production of cheese and casein

	1,000 Tonnes	
	Cheese	Casein
1974-1975	99	14
1975-1976	113	16
1976-1977	104	17
1977-1978*	110	19

*Preliminary

Source: Estimated from Australian Dairy Board Statistics

The major portion of the whey is produced in one state, Victoria, which is the main dairying area located in the southeast corner of the country. Best current estimates indicate that some 15% of the total whey produced (~217,000 tonnes of fluid whey) is presently going to pig feeding. A further 72,500 tonnes of fluid whey are disposed of as fertilizer in land application schemes and about 145,000 tonnes are processed in one form or another. Dried whey solids constitute the major processed form of whey solids. A number of whey-skim milk blends (50% whey solids and 50% skim milk solids) and sweet whey-caseinate blends are also manufactured. The best overall estimate of current utilization of whey is ca. 55%.

A vigorous research program on whey utilization has been pursued in Australia since 1970. The major effort in this area has come from the C.S.I.R.O. Dairying Research Group. The programme, its objectives, and achievements were reported at the Whey Products Conference in 1976 (Muller, 1976). To date, no facility to produce modified whey on a commercial scale has been introduced in Australia. One reason for this has been the unstable inflationary economic situation over the past three to four years. This situation has particularly discouraged investment in the dairy industry. However, investment in whey processing facilities is expected to come very soon, initially, to produce delactosed whey powder and lactose (no lactose is produced in Australia at the present time) and then to produce whey based infant formulations.

NEW ZEALAND

Whey production and utilization in New Zealand was considered by Marshall at this conference in 1976 (Marshall, 1976). Statistics on the production of fluid whey in New Zealand are given in Table XIII. Sweet whey results from the manufacture of cheese, while two types of casein whey are produced--lactic acid casein whey (skim milk is inoculated with a suitable lactic acid culture) and rennet casein whey (rennin is used to clot skim milk).

TABLE XIII.--Production of fluid whey in New Zealand

	Tonnes			
	Sweet	Acid	Rennet	Total
1975-1976	780,000	1,208,000	113,000	2.1×10^6
1977-1978	844,000	1,450,000	150,000	2.4×10^6

Source: Estimated from New Zealand Dairy Board statistics

Manufacturing statistics for whey products for the past four years are included in Table XIV. Virtually all whey based products show an increase. Total lactose production increased by 53% from 7,500 tonnes to 11,650 tonnes in the period 1974/75 to 1976/77. Increases in lactose production are expected to continue. Approximately 25,000 tonnes of whey solids are projected

TABLE XIV.--Manufacture of whey products
in New Zealand

	1974-75	1975-76	1976-77	1977-78
Lactose	7,500	9,400	11,650	---
Whey Butter	2,727	3,040	---	---
Lactalbumin	---	170	500	---
Rennet Whey Powder	1,378	2,900	3,400	9,000
Cheese Whey Powder	---	500	800	---
Delactose Whey Powder	---	860	1,100	---
Infant Foods	6,673	17,000	19,500	---

Source: Estimated from New Zealand Dairy Board statistics

to go towards the manufacture of lactose and delactosed whey powder by the 1980/81 season. The production of lactalbumin increased three-fold from 170 to 500 tonnes over the period 1975/76 to 1976/77. Projected production for the 1977/78 season could exceed 800 tonnes. Lactalbumin, which is produced by the heat precipitation of whey proteins, followed by recovery, washing, and drying, has been manufactured in New Zealand for the past twenty years. The product is also manufactured in the U.S. and in Europe. Formerly in New Zealand, the washed product was roller dried. The current product is spray dried. All the lactalbumin produced in New Zealand is manufactured from lactic acid casein whey.

Rennet whey powder, with its relatively low ash content, is a suitable ingredient for foodstuffs, particularly infant foods, and is being produced in increasing amounts. A six-fold increase in production occurred over the period 1974/75 to 1977/78. With strong market demands, this trend is expected to continue.

In the 1977/78 season, it is estimated that ca. 500,000 tonnes of fluid cheese and casein whey will be returned to farmers for pig feeding. This practice is declining as alternate outlets provide better economic returns. Relatively large quantities of lactic whey are disposed of by spray irrigation. When properly controlled, this is an effective disposal method. Currently, about 12 companies employ this procedure.

Increasing amounts of infant food formulations are being produced in New Zealand. Some contain whey solids, a portion of which have been demineralized. Soluble whey protein concentrates (WPC) are being produced in New Zealand by ultrafiltration (UF). A new De Danske Sukkerfabrikker (DDS) UF

facility with a capacity of 850 tonnes of whey per day was installed in 1977. Projected WPC production for 1977/78 is about 500-600 tonnes.

In general, cheese and rennet wheys are being fully utilized in New Zealand, and, in some cases, demand exceeds supply. Lactic acid casein whey has, however, been less well utilized. This situation is changing rapidly with the production of increasing quantities of lactalbumin and lactose and WPC from lactic acid whey. Total utilization of whey in New Zealand is currently about 85-88%.

WESTERN EUROPE

Data on the production of fluid whey in Western Europe are given in Table XV. Total production of fluid whey in 1977 was about 30.5 million tonnes. In Europe, the whey is generated from the production of hard, soft, and fresh cheeses and casein. The largest single producer of whey in Western

TABLE XV.--Production of fluid whey
in Western Europe

	1,000 Tonnes	
	1973	1975
Belgium	---	351
Denmark	1,147	1,368
France	7,929	8,415
Germany (W)	5,076	5,558
Greece	---	360
Ireland	378	513
Italy	4,320	4,556
Netherlands	2,995	3,371
Spain	405	450
Sweden	639	810
Switzerland	873	914
UK	1,629	2,160

Based on IDF and FAO statistics

Europe is France with 8.4 million tonnes in 1975. France is followed by West Germany, Italy and Netherlands. Totally accurate data on whey production in West European countries are difficult to generate. Production figures for soft and hard cheeses are reasonably easily obtained, but accurate data on the production of fresh cheeses such as quarg are difficult to obtain.

Estimates for the percentage utilization of whey in selected West European countries are given in Table XVI. The utilization of whey in Western Europe is generally high. France, for example, produced 240,000 tonnes of whey powder of all types in 1977. This represents about 56% of the total whey solids produced. An additional 66,000 tonnes of infant food powder (containing ca. 20,000 tonnes of whey solids, some demineralized) were produced. The large number of small cheese producers in France makes the centralized processing of whey difficult in certain areas. Thus, relatively large volumes of fluid whey are fed directly to pigs. In 1977, 12,000 tonnes of lactose were produced in France.

TABLE XVI.--Utilization of whey in
Western Europe 1974/75

	% Utilization
France	85
Netherlands	99
W. Germany	78
Ireland	71
UK	66

Interest in processing of modified whey solids is highest in Europe. Ion exchange treatment of acid whey is in common use in France. Recently a number of electrodialysis systems have been installed. There are three commercial UF systems operating on whey. A small number of commercial reverse osmosis installations have been used to concentrate whey since 1973.

In 1977, West Germany produced ca. 150,000 tonnes of whey powder and ca. 38,000 tonnes of lactose. Three commercial UF installations and one electrodialysis plant are operating on whey. Estimates indicate that approximately 180,000 tonnes of whey powder and 67,000 tonnes of lactose, together with a range of modified whey products, were manufactured in the Netherlands in 1977.

Detailed practices in other individual Western European countries vary to some degree, but interest in newer processing technologies is very high.

Data on the production of fluid whey in various parts of Eastern Europe are given in Table XVII. Little information on utilization patterns is available.

TABLE XVII.--Production of fluid whey
in Eastern Europe

	1,000 Tonnes	
	1973	1975
Bulgaria	---	773
Czechoslovakia	---	953
Poland	2,448	2,822
Romania	---	665
USSR	8,400	9,464
Yugoslavia	---	827
Estimated from IDF-FAO statistics		

SUMMARY

I think that it becomes clear that there are no panaceas or universal solutions to the world-wide problem of whey utilization. There are individual solutions in individual countries at different times. Generally, what is being attempted all over the world is to employ the very valuable solids in whey in a constructive manner and to avoid the expense and waste of disposal. The overall goal is to create new and improved products with an increase in the average value of whey solids. The specific means taken to attain this goal are likely to be different in different parts of the world.

Compositional standards for whey and whey products, standards of identity of products permitting the incorporation of whey solids, and safety regulations are all issues that must be addressed. The International Dairy Federation and Whey Products Institute are active in these areas.

I think it is important to realize that utilization must encompass all of the solids in whey--protein and lactose alike. Changing patterns in the dairy industries, with increasing use of membrane processes in cheese making will affect utilization in the coming years.

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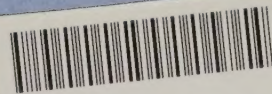
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